A FRAMEWORK FOR PRODUCTION LEVELING IMPLEMENTATION IN BATCH MANUFACTURING: A CONCEPTUAL MODEL

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Abstract*: Intense competition among companies in global value chains keep them helpless under the Bullwhip Effect, which refers to the amplification of the variability of customers´ demand across upstream processes. This phenomenon causes unstable production scheduling patterns, increasing inventory levels and wastes in both process and operations. In order to avoid such undesireble effect, manufacturing companies need to convert uneven production runs into even ones. Therefore, aiming for this paradigm shift, Production Leveling (heijunka) - a Lean Manufacturing concept for Production Planning and Control (PPC) - represents a combination of a leveled schedule pattern and the Kanban System to trigger the replenishment of supermarkets (stock points). Nevertheless, recent researches point out that Production Leveling is not fully understood and is not being implemented among batch production processes. Besides all this, theoretical approaches that has been found at literature are focused on simple models related to assembling lines from automotive supply chains. Regarding those gaps, this paper presents an conceptual model of PPC activities combining Lean Manufacturing tools. Based on that, this paper aims to present a framework that has been designed to support the implementation of Production Leveling in batch production systems. This is expected to help both researchers and practitioners, and highlights the debate of the applicability of related practices outside automakers´ supply chains. Beginning with a literature review, this paper shows the traditional model for PPC activities – featuring the Strategic, Tactic and Operational levels – Lean Manufacturing classification, including level production plan and Kanban System. After that, a conceptual model was depicted by replacing traditional activities of PPC at Tactic and Operational levels. Also, an alternate method for Level Production Plan has been presented and research findinds evidence that this proposed solution makes easier the analysis of the utilization of process capacity. Then, this model is a part of a wider qualitative research related to a case study of an implementation of Production Leveling at a large-size manufacturer – located on state of Sao Paulo, Brazil – that produces industrial goods for a wide range of supply chains in a make-to-stock production policy.*

Keywords*: Batch Production, Framework, Heijunka, Production Leveling*

1. INTRODUCTION

Companies that operate at industrial supply chains are facing strong competition that drives them to search for improvements in their methods for Production Planning and Control (PPC). Hence, as product variation become wider, Mass Production is no longer regarded as the best choice to enable flexibility and good service level to their customers holding less amount of inventory. Additionally, traditional approach for PPC has many features that enable the Bullwhip Effect, a dynamic phenomena that power and transmit the variation of customers´ demand to upstream processes throughout productive stages in a supply chain (Slack *et al.*, 2002; Jones *et al.*, 2004). For this reason, Lean Manufacturing is named as the way to improve business´s competitiveness by leveling the production to meet customer demand faster and spending fewer resources (Jones and Womack, 2004).

The main objective of Production Leveling is to enable a more stable schedule for mixed-model production, by gradually decreasing production batch size and using pull system as a link to connect productive stages in whole supply chain (Monden, 1998; Slack *et al.*, 2002; Smalley, 2004). This also can be regarded as a paradigm shift of methods for PPC, because, in other words, Production Leveling represents a combination of two relevant concepts of Lean Manufacturing: Kanban System - that triggers the production using operational rules for replenishment of supermarket, by controlling work-in-process inventory – and Heijunka, that enables a smother daily production sequencing pattern at assembling lines (Fujimoto, 1999; Koyde and Iwata, 2007).

Nevertheless, in spite of well known relevance of Lean Manufacturing practices, recent research highlight that Production Leveling is still being implemented outside automaker´s supply chains in a very incipient way. Moreover, such limitation support the debate of general applicability of Lean Manufacturing practices (Godinho Filho and Fernandes, 2004). This debate can be divided into three main gaps that have been found at literature review.

First of all, it is true that most of conceptual models are focused on problems related to production sequencing for assembling lines, typically on automaker´s supply chain (Kotani *et al.*, 2004; Bautista and Cano, 2008; Boysen *et al.*, 2007). Secondly, one can argue that very small batch production could not fit properly on a wide variety of manufacturers, even in automaker´s chains (Cooney, 2002). Finally, recent research (Slack *et al.*, 2002; Smalley, 2004) concerning Production Leveling are based in simple models, and for this reason, it can be said that there was no explicit method based on Production Leveling application for batch production processes, such as plastic injection, plastic extrusion, press stamping and so forth.

To synthesize, the method for an effective implementation of Production Leveling in batch production manufacturers still remains unknown. Thus, based on those exposed gaps, this paper presents a conceptual model that has been designed to support the implementation of Production Leveling in a batch manufacturer, as a part of a wider quantitative research based on a case study of a large size company, located on state of São Paulo, Brazil, in early 2008 (Araujo, 2008). This is the major contribution of this paper which limitation is focused on make-to-stock (MTS) production policy for repetitive manufacturing systems and industrial applications for a single process.

Hence, this paper is structured as follows. In section 2, the research methodology is explained. In section 3, the literature review of the main concepts is presented, including the traditional framework for PPC and its related activities. In section 4 presents a framework for implement Level Production as well its related activities. Moreover, regarding the classification of Lean Manufacturing as a method for PPC, the Level Production Plan is commented and also an alternate method is proposed. This paper ends with conclusion and final comments of proposed method in section 5.

2. RESEARCH METHODOLOGY

Based on objectives of this paper, the methodological approach comprises a literature review of Operations Management and Lean Manufacturing concepts. Therefore, by analyzing traditional concepts for PPC, and regarding the classification of Lean Manufacturing as a method for PPC, the proposed framework is explained for Production Leveling as well its main activity named Level Production Plan. After that, based on gaps found in literature review, an alternate method to calculate a Level Production Plan is also described.

3. LITERATURE REVIEW

This section summarizes the main concepts related to PPC and includes a traditional framework of PPC, Production Planning at Toyota and Level Production Plan. All those elements have been combined into a proposed framework, as shown at section 4.

3.1. Traditional framework of PPC

In mass production systems, decisions concerning activities of PPC depend on planning time horizon, more specifically the period of time ahead the actual date. In this context, a traditional framework for PPC activities can be summarized linking three levels of decision making process (Strategic, Tactical and Operational), as depicted accordingly to Fig. 1 above:

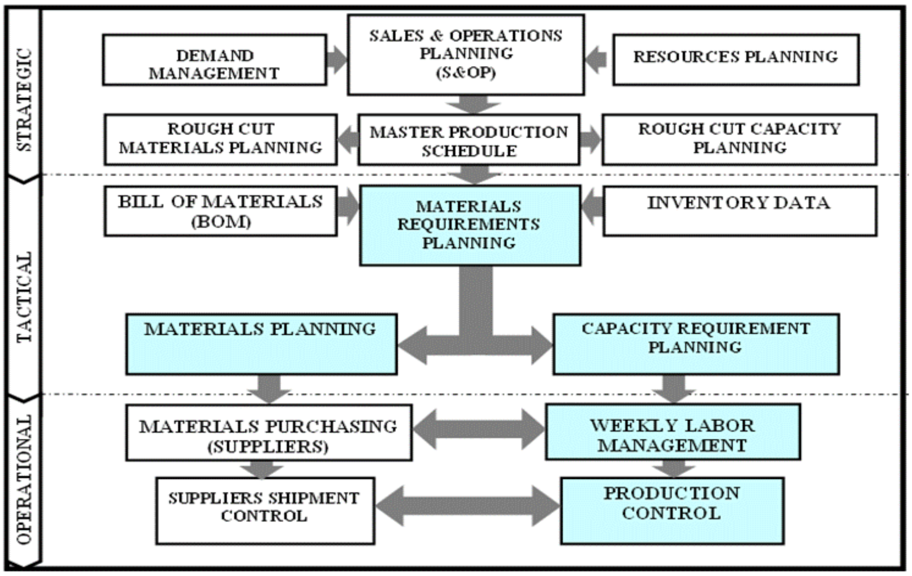

Figure 1. Traditional framework for PPC activities, divided into three levels of planning. Source: Araujo (2008)

The three mentioned levels are related to planning horizon, from the strategic to operational, as defined as follows (Araujo, 2008):

i. Strategic: Related to long term production planning and features the activities of Sales and Operations Planning (S&OP) e the main input to the Master Production Schedule (MPS)

ii. Tactical: regarded as medium term production planning which has data processing from MPS, monthly planned demand is set aiming to generate both materials and capacity planning. Usually, a software for Materials Requirement Planning (MRP) is applied to such activities, providing materials purchasing lists, labor and inventory requirements, as well the necessary availability of machinery and productivity assets;

iii. Operational: referred as short term planning horizon at 'shop floor' level. This contains weekly labor scheduling (normal and extra time requirements) as well the five activities for production control: loading, sequencing, scheduling, dispatching and control.

These activities comprises decisions that become more difficult as the supply chain become more complex, that is, for a wider variety of products, uncertainties of the demand of the market and the number of productive stages. Based on these definitions, the department of Sales can manage the customers´ demand by means of the analysis of the ordering system (backlog) and data generated from methods of demand forecast. Then, the information system, usually MRP software, allows to the register of the due date of delivery to the customers, generating updated information for the production scheduling (Slack *et al.*, 2002).

3.2. Production Planning at Toyota

The main difference between traditional PPC and Lean Manufacturing one concerns both tactical and operational levels (Vollmann *et al.*, 2006), which are the focus of this paper. Moreover, in very general way, the Production Planning of Toyota is a system that can be divided into two phases, called 'Monthly Adaptation' and 'Daily Adaption'. The former is related to activities of medium term horizon and is developed based on demand forecasting for a wide variety of vehicles. The latter comprises to the production planning at short term level and contains the activities for production scheduling and control at operational level (Monden, 1998).

3.3. Tactical and Operational Level of Lean Manufacturing

Based on previously exposed context, Lean Manufacturing can be classified as a Production Philosophy, a set of techniques for operations management and a method for PPC, whereas operations must provide a very high level of flexibility, quality, speed, reliability and cost (Slack *et al.*, 2002).

The tactical level of PPC begins from data gathering from MPS, by providing detailed information to a Level Production Plan, as depicted in Fig. 2. Furthermore, the simplified Bill of Materials (BOM) enables a simpler materials planning of finished goods inventory produced on final assembling line (Vollmann *et al.*, 2006). Moreover, based on latest revision of MPS, inventory level can be sized properly based on demand forecast throughout supply chain.

That information gives an input for short term planning at shop floor and the daily schedule is sent only to the final assembling line (pacemaker process) and upstream processes will be triggered by using Kanban System to replenish stock points (supermarkets) with the exact amount of items at right time. To enable this feature, inventory level of every upstream process is sized based on dependent demand system related to BOM (Monden, 1998).

3.3.1 Level Production Plan

As part of the planning at tactical level, the level production plan in such a way supplies input to the materials planning concerning the balance between plant loading and its required capacity, as well in the traditional model of PCP as previously depicted in Fig. 1. Such concept has left of a demand forecast for the next month and consists of the distribution of the product mix over the period of time, generally lesser that ten days. If the consumption rate is leveled, then the signal of replenishment to the suppliers and upstream processes also will be. For this reason, it is possible to keep small quantity of inventory, as the consumption becomes more predictable (Liker and Meier, 2007). This condition is the ground of the Production Leveling concept. Moreover, three decisions are necessary to achieve a leveled production (Smalley, 2004; Liker and Meier, 2007):

1. Product volume, which refers to the production batch size over a period of time, also called Production Pitch or Pitch.
2. Product mix, which is the proportion of various model that must be produced during the period of time
3. Production sequence, which is the order that the product volume and mix must be produced

In batch manufacturing systems, set up time affects production batch size as well the decisions of daily production scheduling. Based on that, Production Leveling becomes more difficult to be implemented as product variety increases. Because of that, practitioners shall start leveling process with bigger batch sizes, whereas particular actions must be done to enable the reduction of set up time of operations and processes (Shingo, 1996).

Considering those previously explained concepts, the leveling of volume and mix comprises a Level Production Plan that gives an possible leveled schedule pattern, (LEI, 2009; Liker and Meier, 2007) that enables the analysis of available capacity required to define production cycle of product mix. This plan is depicted as follows on Tab. 1:

Table 1. Possible Leveled schedule pattern with 8 days of time horizon. Source: Araujo (2008).

Model	**Production Cycle**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total Volume (parts)**
A	1D	250	250	250	250	250	250	250	250	2,000
B	1D	220	220	220	220	220	220	220	220	1,760
C	1D	210	210	210	210	210	210	210	210	1,680
D	2D	256	0	256	0	256	0	256	0	1,024
E	2D	0	250	0	250	0	250	0	250	1,000
F	2D	150	0	150	0	150	0	150	0	600
G	4D	0	240	0	0	0	240	0	0	480
H	4D	0	0	0	180	0	0	0	180	360
I	4D	180	0	0	0	180	0	0	0	360
J	4D	0	0	140	0	0	0	140	0	280
Others	MTO	59	155	99	215	59	155	99	215	1,056
Load	Total	1,325	1,325	1,325	1,325	1,325	1,325	1,325	1,325	10,600
Capacity	Target	1,325	1,325	1,325	1,325	1,325	1,325	1,325	1,325	10,600

Table 1 depicts a possible leveled production pattern within 8 days of time horizon. The first left column contains the product mix, labeled as uppercase letters, from A to J. Model named as 'Others' means a group of product models with lower demand that must be produced in a make-to-order (MTO) policy basis (Liker and Meier, 2007).

The second left column indicates production cycle expected to meet total volume listed on first right column. This table also depicts production cycle of every day (1D), every 2 days (2D) and every 4 days (4D). Moreover, column head labeled as '1 to 8' refer to productive days of the plan. Finally, 'Total Volume' means the planned demand amount that has been set for current month.

To set a leveled production pattern, is necessary to sort the product list by descending order of Demand (Total Volume). After doing that, the model with higher demand is set as '100%' and, based in this sample, model A has the higher value of total volume (2.000 parts), which production cycle is set as every day (1D), as shown in Tab. 2:

Table 2. Rule for definition of production cycle and batch sizes. Source: Araujo (2008).

Models of Products	Total Volume (Parts)	Relative Demand to A Model	Production Cycle	Average Daily Demand (parts)	Number of Set up at Interval	Number of Set up at Month	Batch Size (Parts)
A	2,000	100%	1D	250	8	24	250
B	1,760	88%	1D	220	8	24	220
C	1,680	84%	1D	210	8	24	210
D	512	51%	2D	128	4	12	256
E	500	50%	2D	125	4	12	250
F	300	30%	2D	75	4	12	150
G	120	24%	4D	60	2	6	240
H	90	18%	4D	45	2	6	180
I	90	18%	4D	45	2	6	180
J	70	14%	4D	35	2	6	140

Similarly, models B and C, whose relative demand are greater than 50%, have also every day cycle (1D), whereas models which relative demand is located between 25% and 50% are set to every 2 days (2D) – models D, E and F – and finally, models up to 25% must be set as every 4 days (4D). After defining production cycle, number of set up over the 8 days interval is automatically set. For instance, every day cycle means 8 set up within interval, as well every 2 days cycle means 4 set up at same interval. Additionally, average daily demand is set by dividing total volume by 8, and at last, production batch size is set by dividing Total Volume by number of Set up at Month. Those simplified calculations are also depicts in previous Tab. 2.

4. PROPOSED FRAMEWORK FOR PRODUCTION LEVELING

This section presents a proposed model framework to support the implementation of Production Leveling in batch manufacturing systems. Hence, an alternate method to develop a level production plan is also presented. First of all, the traditional framework for PPC has been modified by replacing traditional activities by Lean Manufacturing tools. Such changing is depicted in Fig. 2:

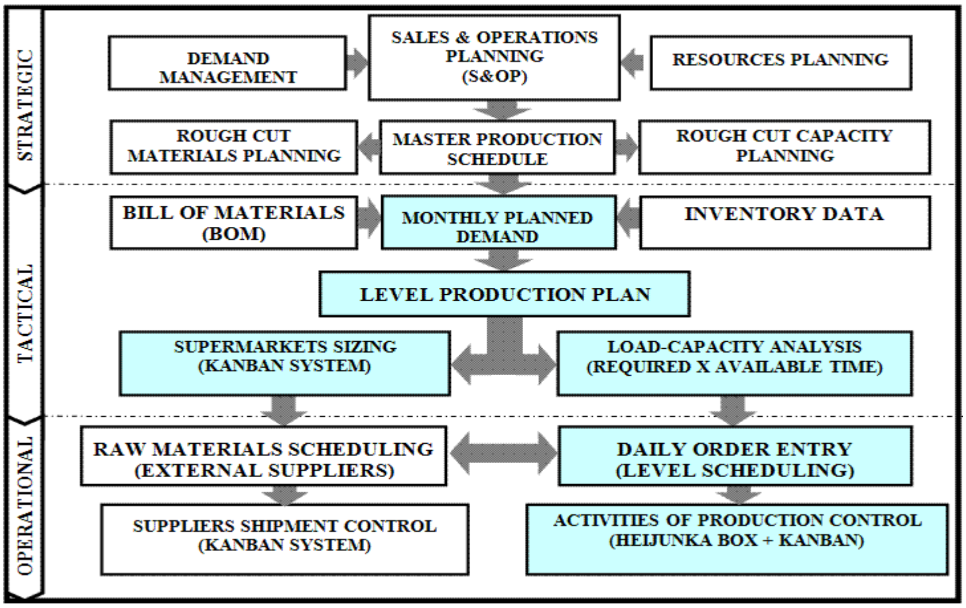

Figure 2. Proposed framework of Production Leveling activities. Source: Araujo (2008)

This model, focused particularly at tactical and operational levels highlighted at blue boxes, comprises the following activities:

1. Monthly Planned Demand: Based on inventory data, bill of materials and customers´ ordering backlog, materials planners set, for every product model, its related planned volume for the actual month. The planning process also takes into account two decisions to damp the variation of the customers´ demand. First, is necessary to define the strategies of positioning of the products, that is, to size the finished goods inventory combining the make-to-stock policy. Secondly, safety stock is sized to enable protection against product stock out due peaks of demand and internal problems caused by defective parts, machine downtime and so forth.
2. Level Production Plan: based on monthly planned demand previously set, this activity comprises a leveled pattern for a desired condition regarding production batch size, set up time and the balance between required and available capacity. This plan outputs provides input to two following activities.
3. Supermarket sizing: refers to stock point sizing throughout production chain, using particular method based on Kanban System principles. Furthermore, by deciding how much finished goods are expected to be sold, every stock point throughout production chain can be also defined.
4. Load-capacity analysis: based on outputs from Level Production Plan, managers can decide whether or not total available time is enough to run planned demand regarding every product model and its related production cycle. Adjustments in labor, working time and available process shall be done in order to provide an acceptable balance between load and capacity to meet customers´ demand.
5. Daily order entering: comprises as the set of decisions about daily level scheduling in order to replenish stock point levels. Also comprises five activities of production control: loading, sequencing, scheduling, dispatching and control. In such activities, visual controls are set to help operators, coordinators and supervisors, as well and materials handlers to sustain a stable production flow.

Those activities, combined into a proposed framework, shows that all planning activities must be connected to each other by using tools of Lean Manufacturing. That is, it has been developed to provide support for implementation of Production Leveling when sustainable changes have been implemented at studied company (Araujo, 2008). Such company has experienced improvements in such PPC method as well in overall performance like inventory reduction and productivity improvement.

Based on this previously exposed framework, a Level Production Plan means the core of this research because it provides relevant input to both materials and capacity planning. Based on that, original method found in literature review has been replaced to an alternate method that is explained in the following section.

4.1. Alternate method for level production plan

This section provides a brief explanation referred to major contribution of this paper. In other words, it comprises a simplified analysis of utilization of available capacity of a process. Based on literature elements previously described, the proposed alternate method comprises, in short, three main decisions: prioritize product models, select the interval and level the required capacity. Such information is shown in the following subsections.

4.1.1. Prioritization of products – Pareto´s Principle

After decisions concerning monthly planned demand for every product variation, production planner must prioritize items to set the level production plan. First of all, one can select a time horizon that is means a planning interval. Usually, such decision is grounded on Pareto principle that means 80% of monthly demand corresponds to 20% of product models variation.

4.1.2. Selection of the interval

In general ways, interval could be set as 6, 7, 8, 10 or more days for planning time horizon (Liker and Meyer, 2007). Thus, a very important issue is that there is no particular rule to define a better interval. It is depends on kind of manufacturing system and its related constraints, such as production batch size, set up time, total available time, and so forth.

4.1.3. Proposed method for leveling the required capacity

Decisions for Production Leveling comprise two options: level the load within the interval or level the required capacity needed to process batches for every product model. The former is related to batch sizes for every single product model and it depends on three parameters: available capacity of pacemaker process in terms of production rate (parts per minute); monthly planned demand from MPS for every selected product model and interval of planned demand. The latter fits better in manufacturing system with batch production, which production rate can vary to one product to another. Because of that, instead of leveling the load, it is preferred to leveling its correspondent required capacity related to 'Production Pitch' or 'Pitch'. In other words, this concept means the total amount of time elapsed to process one production batch for one selected product model. So, based on this previous definition, Production Pitch is described by Eq. (1):

$$PPi = STi + PTi \tag{1}$$

Given:

PPi = Production Pitch for product model i (minutes)
STi = Set up time for product model i (minutes)
PTi = Processing time for product model i (minutes)

Processing time is equal to process run time needed to produce a single batch for one product. So, it is set by Eq. (2):

$$PTi = \frac{PBi}{PRi} \tag{2}$$

Given:

PTi = Processing Time for production batch i (min)
PBi = Production Batch for product model i (parts)
PRi = Production Rate for product model i (parts per minute)

After that, the next shown Eq. (3) is set by combining both Eq. (1) and (2):

$$PPi = STi + \frac{PBi}{PRi} \tag{3}$$

Based on previously listed equations, and replacing given variables values at Eq. (3), an example is shown for product model A previously listed on Tab. 2:

Given:
STi = 25 min
PRi = 1.33 parts/min
PBi = 200 parts

PPi = 25 [min] + 200 [parts] / 1,33 [parts/min]
PPi = 213 min

It means that it takes 213 min to process on single batch with 200 parts for a given product model A. Hence, repeating this procedure for all selected products by using PR = 1.33 parts/min, results are summarized on Tab. 3:

Table 3. Production Pitch calculation sample for given product models. Source: Araujo (2008).

Model	Total Volume (Parts)	Relative Demand to A Model	Cycle	Batch size (parts)	Production Rate (parts/min)	Set up time (min)	Pitch (min)
A	2,000	100%	1D	250	1.33	25	213
B	1,760	88%	1D	220	1.33	25	190
C	1,680	84%	1D	210	1.33	25	183
D	512	51%	2D	256	1.33	25	217
E	500	50%	2D	250	1.33	25	213
F	300	30%	2D	150	1.33	25	138
G	120	24%	4D	240	1.33	25	205
H	90	18%	4D	180	1.33	25	480
I	90	18%	4D	180	1.33	25	160
J	70	14%	4D	140	1.33	25	390

The first right column shown on tab. 3 has values for calculated Production Pitch for product models from ‘A to J’. After that, such values will be applied on Level Production Plan. However, it is worth explaining that Production Pitch can vary among various product models and this is a very common issue for batch manufacturing systems. Indeed, the total daily available time constraints the number of production batches that can set for daily scheduling.

Based on that assumption, the Level Production Plan must be finalized for every selected product model and its related Production Pitch. This feature simplifies the analysis of available capacity by adding a reference for required capacity instead of required volume (load). That is why there are two sources of waste of available capacity in batch manufacturing: Bigger production batches increases total waiting time and production lead time. In the other hand, running very small production batches increases the total set up time at the short term. Both of them shall be affect the ability to meet customers´ demand on time and then must be avoided by performing an analysis of capacity. Such feature is the major contribution of this proposed method. Finally, a Level Production Plan with Production Pitch is shown on Tab. 4:

Table 4. Level Production Plan sample for 8 days of time horizon with production cycle, production batch size and its related production pitch for selected product models. Source: Araujo (2008).

Product Models	1	Pitch (min)	2	Pitch (min)	3	Pitch (min)	4	Pitch (min)	5	Pitch (min)	6	Pitch (min)	7	Pitch (min)	8	Pitch (min)
A	250	213	250	213	250	213	250	213	250	213	250	213	250	213	250	213
B	220	190	220	190	220	190	220	190	220	190	220	190	220	190	220	190
C	210	183	210	183	210	183	210	183	210	183	210	183	210	183	210	183
D	256	217			256	217			256	217			256	217		
E			250	213			250	213			250	213			250	213
F	150	138			150	138			150	138			150	138		
G			240	205							240	205				
H							180	160							180	160
I	180	160							180	160						
J					140	130							140	130		
Daily Required Capacity (min)		1,168		1,143		1,168		1,143		1,168		1,143		1,168		1,143
Total Daily Available Time (min)		1,215		1,215		1,215		1,215		1,215		1,215		1,215		1,215
Total Daily Remaining Time (min)		46		71		46		71		46		71		46		71
Daily Available Capacity Utilization (%)		**96%**		**94%**		**96%**		**94%**		**96%**		**94%**		**96%**		**94%**

Table 4 summarizes the alternate calculation of Production Pitch related to product models shown on Tab. 3 with given ST = 25 min e PR = 1,33 parts/min for every product model. Moreover, more information can also be found at Tab. 4 as follows.

1. Each column labeled as '1' to '8' comprises production batch size whereas columns labeled as "Pitch" are related to respective Production Pitch for every Product Model located at Tab. 4 first left column and labeled from 'A' to 'J'.
2. The last 4 rows of Tab. 4 comprise the necessary information to perform an analysis of utilization capacity for this studied process. Therefore the sum of each column labeled as 'Pitch' comprises the daily required capacity
3. The total Available time is the sum of 3 shifts of 450 min each, minus 60 min each for lunch and 15 min each for daily shift meetings. All unpredictable breakdowns have not been taken into account.
4. Leveling the load and capacity means to distribute production batch size, production pitch and production cycle (1D, 2D and 4D) over the interval. Such information are placed at every row of Tab. 4
5. The analysis of utilization of capacity features a percentage of time that must be expected to be daily runs for every batch in a Level Scheduling. Thus, such analysis is performed by comparing both Daily Required Capacity and Total Daily Available Time. Based on this sample, the average utilization of capacity is 95% within the interval of 8 days horizon.

It is worth highlighting that such concepts simplify learning about proposed method. Indeed, Tab. 4 also shows that there are differences among production batch sizes and production pitches for every product model. For this reason, this comprises a typical condition in many manufacturing systems.

5. CONCLUSIONS

Competitiveness at global markets leads companies to rethink existing methods for Production Planning and Control (PPC). Such paradigm shift highlights the Production Leveling, a simplified approach of Lean Manufacturing for PPC activities. However, despite of its relevance, researches point out that there are gaps in literature that make hard to implement Production Leveling in batch manufacturers. For this reason, this paper provides a new framework that has been implemented in a multinational company, located on state of São Paulo, Brazil, as a part of a wider qualitative research in early 2008. This research is going to be presented in a future paper.

Proposed method has been developed by means of critical analysis of concepts related to Operations Management, particularly PPC. Starting by a brief explanation of traditional approach of PPC, its related activities have been listed. After that, regarding the classification of Lean Manufacturing as a set of techniques for PPC, a brief explanation of Tactical and Operational activities at Toyota has been shown. Based on this information, a proposed framework has been designed by replacing traditional activities by Lean tools. For instance, decisions for setting Monthly Planned Demand instead of traditional analysis of MRP have been taken in place.

The proposed framework for Production Leveling starts at Tactical Level, which decisions related to monthly planned demand and safety stock policies aiming to set how much products are expected to be sold at actual month. By setting such values, a Level Production Plan is calculated in order to get a better balance between total volume and production batch size. By doing this, one can set production cycle for every product model regarding existing process constraints. This plan also gives input for both materials and capacity planning. After that, activities related to Operational Level can be set for shop floor personnel run a daily level scheduling using preset batch sizes and visual controls.

Moreover, the Level Production Plan with the original concept for leveling the load for a given interval has also been explained. In addition, an alternate method for Production Leveling has been commented, featuring the prioritization of product models, selection of interval of leveling and the concept for leveling the required capacity. It has been motivated by gaps found at literature review which has lead to a combination of theoretical elements regarding Lean Manufacturing principles, such as both recent research as well classical publications of Toyota Production System.

Despite of the simplicity of Level Production Plan, the alternate method explained in this paper makes easier to both practitioners and researches to understand how to implement Production Leveling in batch production systems.

To conclude, research findings evidence that this proposed alternate method for Level Production Plan provides a simplified decision making method based on Lean Manufacturing concepts for Production Leveling. In other words, for a given set of product models, production batch size and production cycle can easily be estimated, based on available capacity of process and its related constraints. It is worth pointing that regarding on research limitation is still necessary to replicate this methodological approach in future researches to confirm its general applicability in different scenarios for make-to-stock policy as well to perform such study for batch manufacturing systems in a make-to-order policy. In that case, it is worth stating Lean Manufacturing must be implemented as a whole in order to provide sustainable improvements.

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