PLANNING THE INFLOW OF PRODUCTS FOR PRODUCTION LEVELLING

M.Sc. Eng. Rewers R.
Faculty of Mechanical Engineering and Management – Poznan University of Technology, Poland

paulina.rewers@put.poznan.pl

Abstract: *Production levelling, also referred to as production smoothing (jap. Heijunka), is an effective method for reducing unevenness in the production process and maintaining better control over stock levels. It helps keep production at a steady pace and ensure the desired level of flexibility. The authors present a study aimed at developing a method for planning the inflow of products from the production process, intended to be used in the scheduling of levelled production. Focus has been put on finding the right combination of lot size and production interval which, assuming certain input parameters (order size and placement rate, initial stock levels), yields the best outcome in terms of timely/untimely order fulfilment and minimum and maximum stock levels.*

Keywords: PRODUCTION LEVELLING, LEAN MANUFACTURING, SIMULATION

1. Introduction

In the market conditions prevailing these days, demand can be anything but steady. Enterprises striving to remain competitive need to adjust to a rapidly changing environment.

To keep up with the fluctuation of demand, manufacturing enterprises increase their stock levels or enhance flexibility of the production system [1]. Higher stock levels have a stabilizing effect on the production process on the one hand, but drive the cost of warehousing upwards and lengthen the production cycle as the lot size increases, thus reducing flexibility of the production system on the other [2].

A flexible production system is synonymous with the ability to react to sudden peaks in demand, relying on putting orders through directly to the production system. The resulting irregular production schedules generate overtime or idle time [3].

Heijunka is a happy medium which stabilizes the production schedule on the one hand and ensures the required flexibility of the production system on the other [4]. Production levelling has been gaining reputation recently for being an effective tool to smooth out the production process and improve stock level management [5]. Heijunka flattens out peaks in production by ensuring cyclical, fixed production schedules. The schedules are aimed to even-out the production process without increasing stock levels. Sadly, however, many manufacturing enterprises find it extremely difficult to set up fixed production schedules due to uneven production processes caused by high machine failure rate, lack of standards, etc. Therefore, before implementing the principles of Heijunka, it is essential to get production under control, e.g., with the use of Lean Manufacturing methods and tools [6, 7].

The underlying assumption of production levelling is to manufacture small lots of goods at short intervals. Determining the right lot size and production interval to meet customer demand and not exceed the maximum stock level may be challenging [8].

This study is aimed at developing a method of planning the inflow of products from the production process, to be used for scheduling levelled production. For the purpose of the study, a simulation model has been created in Microsoft Excel.

2. Production levelling

Production levelling is a planning technique oriented at even inflow of goods from the production process. It requires the determination of sequence and rate of inflow of goods from the production process in a way to sell directly from the warehouse and avoid sudden changes in the production schedule [9-12]. The production plan must be repeatable and not cause sudden peaks or delays. With production levelling, enterprises can get the inflow of goods from the production process and stock levels under control.

There is an array of interpretations of production levelling in the literature. Some of them define production levelling as a method for:

- increasing production capacity [13],
- reducing stock levels [14],
- preventing work overload [15],
- increasing competitiveness [16],
- smoothing out peaks in production [17],
- manufacturing for stock [18].

The concept of production levelling was developed by Toyota for the automotive industry more than 50 years ago [19]. Heijunka, in combination with work standardization and Kaizen, are the fundamentals of management at Toyota Production System (TPS) [20].

Many authors deal with implementation of production levelling in various industries. Abdulmalek and Rajgopal [21] described the implementation of Heijunka in the steel industry, as one of the components of Lean transformation, together with mapping the value stream, SMED, 5S, JIT, and TPM. Huchmeier et al. [13] conducted a comparative analysis of Heijunka and Just in Sequence (JIS) on the basis of a case study at a BMW engine manufacturing plant. The study proved the supremacy of Heijunka over JIS in terms of smoothing out the highest production peaks. Runkler [22] compared Heijunka and Kanban on the basis of a manufacturer of electronic circuits. With a steady demand and a proven sales history, Heijunka provided a better result than Kanban in terms of stock levels and order fulfilment capacity.

3. Methodology of production levelling

The methodology of implementation of production levelling in a manufacturing plant has been discussed by several authors [5, 18, 23, 24]. However, the solutions proposed are difficult to implement in a real manufacturing environment, considering their high level of generalisation and complexity.

Long research has led these authors to the development of an original production levelling methodology, described in [10-12]. The methodology consists of five stages, as shown in Fig. 1.

At stage one, a group of products for which levelling is to be implemented first is selected. The group contains mainly best-sellers and products sold in large quantities. Next, the products are grouped into families based on their structural and technological similarity. At the following stage, the stock replenishment rate is calculated using the EPEI (Every Part Every Interval) method. At stage four, stock levels (rotational, buffer and safety) are calculated. However, the crucial and most challenging is the last stage, at which a levelled production plan is developed. At this stage, three factors need to be taken into consideration:

- lot size,
- production intervals, and
- sequence in which product families are manufactured.

The authors focus on finding the right combination of lot size and production intervals which, assuming certain initial input parameters, yields the best outcome in terms of timely/untimely order fulfilment and minimum and maximum stock levels.

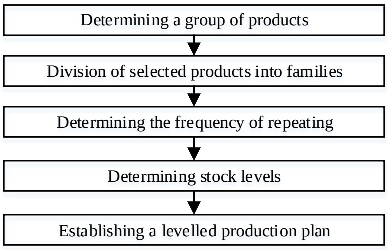

Fig. 1 *. Production levelling methodology, source: own*

4. *Simulation model of product inflow planning method*

4.1. General information

The initial simulation model has been developed in Microsoft Excel (Fig. 2).

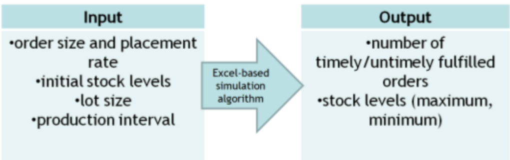

Fig. 2. *Product inflow planning model, source: own*

The model required the following input data (Table 1):

- lot size,
- production interval,
- initial stock levels,
- order size and placement rate (mean value and standard deviation).

Table 1: *Simulation model input data, source: own.*

	Symbol	Value
Production interval	o =	1
Lot size	p =	200
Initial stock levels	m_p =	1400
Order size, mean value	wielk_zam_sr =	1000
Order size, standard deviation	wielk_zam_odch_st =	10
Order placement rate, mean value	czestosc_sr =	3
Order placement rate, standard deviation	czestosc_odch_st =	1

The output data include:

- number of timely and untimely fulfilled orders (“timely” means upon order placement),
- stock levels (minimum, maximum).

Fig. 3 shows the proposed model and output data.

The model is based on four assumptions:

- there is a determined product family,
- the required capacity of the production system is available,
- the time unit is a working day,
- orders are generated at random, according to a regular schedule with a certain mean value and standard deviation.

The simulation is aimed to find the combination of lot size and production interval which, assuming certain parameters (order size and placement rate, initial stock levels), will yield the best outcome in terms of timely/untimely order fulfilment and minimum and maximum stock levels.

Day	Lot size	Stocks levels	Order size	The size of stocks after the order is completed	Order realized?
1	200	1400	1003	397	yes
2	200	597			
3	200	797			
4	200	997	994	3	yes
5	200	203			
6	200	403			
7	200	603			
8	200	803			
9	200	1003			
10	200	1203	1004	199	yes
11	200	399			
12	200	599			
13	200	799			

Orders realized	3
Orders unrealized	0
Minimum stocks level	203
Maximum stocks level	1400
Number of orders	3

Fig. 3. *Example model and output data, source: own*

4.2. Simulation variants

Three simulation variants were determined. In each variant, one of the input parameters was changed. Each simulation was repeated 100 times; each time a random order size and placement rate was generated in accordance with a regular schedule and the relevant input data. The study results are shown in graphs representing the number of timely and untimely fulfilled orders (in percentage values) and the minimum and maximum stock levels.

Variant 1

In variant 1, the production interval and lot size change, the other parameters remain constant (Tab. 2). An assumption is made that the customer orders on average 1000 units every 10 days. The simulation is supposed to find an answer to the question: should the company manufacture 1000 units every 10 days, 100 units daily or 500 units every 5 days?

Table 2: *Variant 1, input data, source: own.*

	Symbol	Value
Production interval	o =	1
Lot size	p =	100
Initial stock levels	m_p =	1400
Order size, mean value	wielk_zam_sr =	1000
Order size, standard deviation	wielk_zam_odch_st =	10
Order placement rate, mean value	czestosc_sr =	10
Order placement rate, standard deviation	czestosc_odch_st =	1

The following input data options were used in variant 1:

- 1: manufacturing 100 units daily,
- 2: manufacturing 200 units every two days,
- 3: manufacturing 500 units every five days,
- 4: manufacturing 1000 units every 10 days.

The simulation results are shown in Fig. 4 and 5. A negative value of stock level represents the maximum number of units the plant is short of to fulfil the order.

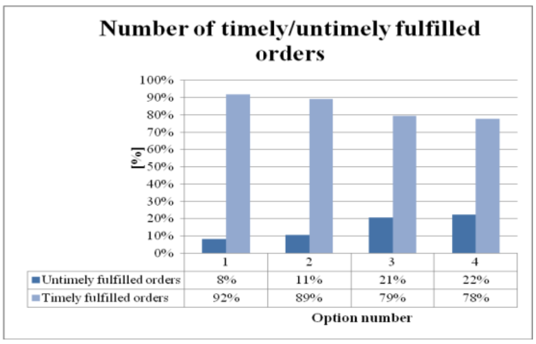

Fig. 4. *Number of timely/untimely fulfilled orders, broken down by options, source: own*

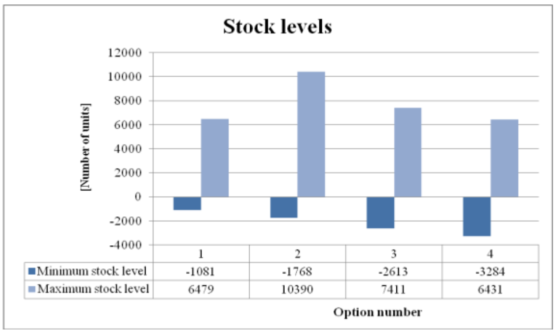

Fig. 5. *Minimum and maximum stock levels, broken down by options, source: own*

Variant 2

In variant 2, the mean value of order size changes, while the other parameters remain constant (Table 3). An assumption is made that the customer orders on average 1000 units every 10 days. The simulation is supposed to find an answer to the question: if the customer changes the order size, will the company be able to fulfil the orders with the manufacturing output of 100 units daily?

Table 3: *Variant 2, input data, source: own.*

	Symbol	Value
Production interval	o =	1
Lot size	p =	100
Initial stock levels	m_p =	1400
Order size, mean value	wielk_zam_sr =	1000
Order size, standard deviation	wielk_zam_odch_st =	10
Order placement rate, mean value	czestosc_sr =	10
Order placement rate, standard deviation	czestosc_odch_st =	1

The following input data options were used in variant 2:

- 1: mean order size 800 units,
- 2: mean order size 900 units,
- 3: mean order size 1000 units (base option),
- 4: mean order size 1100 units,
- 5: mean order size 1200 units,
- 6: mean order size 1300 units,

The simulation results are shown in Fig. 6 and 7.

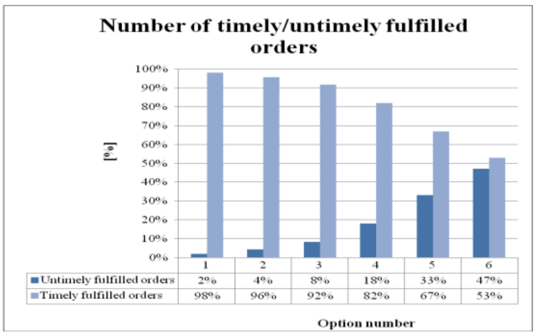

Fig. 6. *Number of timely/untimely fulfilled orders, broken down by options, source: own*

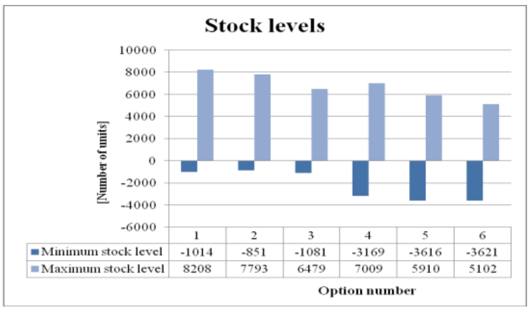

Fig. 7. *Minimum and maximum stock levels, broken down by options, source: own*

Variant 3

In variant 3, the mean order placement rate changes, while the other parameters remain constant (Table 4). An assumption is made that the customer orders on average 1000 units every 10 days. The simulation is supposed to find an answer to the question: if the customer changes the order placement rate, will the company be able to fulfil the orders with the manufacturing output of 100 units daily?

Table 4: *Variant 3, input data, source: own.*

	Symbol	Value
Production interval	o =	1
Lot size	p =	100
Initial stock level	m_p =	1400
Order size, mean value	wielk_zam_sr =	1000
Order size, standard deviation	wielk_zam_odch_st =	10
Order placement rate, mean value	czestosc_sr =	10
Order placement rate, standard deviation	czestosc_odch_st =	1

The following input data options have been assumed in variant 3:

- 1: mean order placement rate – every 7 days,
- 2: mean order placement rate – every 8 days,
- 3: mean order placement rate – every 9 days,
- 4: mean order placement rate – every 10 days (base option),
- 5: mean order placement rate – every 11,
- 6: mean order placement rate – every 12 days.

The simulation results are shown in Fig. 7 and 8.

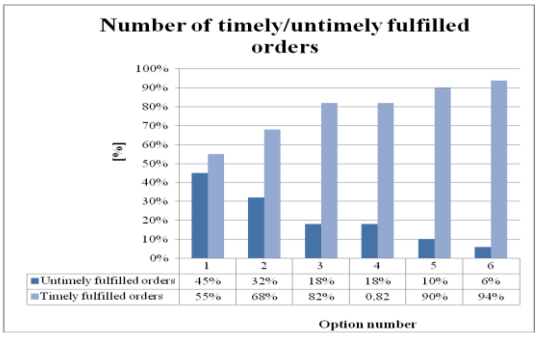

Fig. 7. *Number of timely/untimely fulfilled orders, broken down by options, source: own*

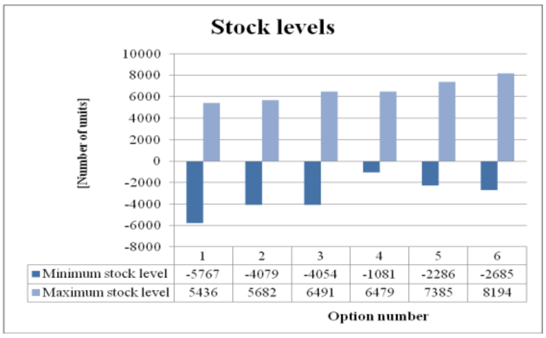

Fig. 8. *Minimum and maximum stock levels, broken down by options, source: own*

5 Conclusions

Production levelling helps maintain a fixed production schedule on one hand and ensures a certain level of flexibility of the production system on the other, while keeping the stock at a minimum required level. The study presented above is aimed to develop a method of planning the inflow of products from the production process. The method will be used for production levelling.

The authors focus on finding the right combination of lot size and production interval which, assuming certain input parameters (order size and placement rate, initial stock levels), will yield the best outcome in terms of timely/untimely order fulfilment and the minimum and maximum stock levels. A Microsoft Excel-based simulation model has been developed for the purpose of the study. Three simulation variants have been distinguished:

- in variant 1, the production interval and lot size change,
- in variant 2, the mean order size changes,
- in variant 3, the mean order placement rate changes.

In variant 1, the best timely order fulfilment rate is obtained with 100 units manufactured daily. Moreover, this option provides optimum (minimum and maximum) stock levels.

In variants 2 and 3, the scope of changes in customer demand is examined relative to the order fulfilment rate and stock levels. This is a preliminary study which, when fully fledged, is aimed to find the range of fluctuation in demand within which the company will be able to meet customer demand while maintaining a fixed production schedule.

The authors describe only a part of the study in progress. At present, simulations are conducted for various input data, as well as works to develop a simulator in the FlexSim simulation software to map a real production system.

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