Integrated Production and Simulation
Scheduling Tool to Solve the Mix Model
Assembly Line Problem Considering Heijunka
and Operational Constraints: a Case Study

Maheut J¹, Garcia-Sabater J.P, Garcia-Sabater J.J

Abstract This article presents a tool based on a customised spreadsheet and a
simulator based on discrete events to solve the production scheduling problem of a
mix model assembly line type of a manufacturing firm in the electrical compo-
nents sector. The problem to be solved must consider the availability of some
products, setup times, manufacturing heterogeneous sized batches, and prioritis-
tion of customers’ orders. The tool described herein has been implemented and
used in a multinational firm located in Spain.

Keywords: Mixed Model Assembly Line, Heijunka, Production Scheduling, Sim-
ulation, Algorithm, Case Study;

1 Introduction

One of the keys to fulfil major Lean implementation objectives is the so-called
Heijunka or “Stability in the Plan”. Heijunka, a Japanese term, is one of the keys
for any Lean system (Womack, 1990, Liker 2004). Although many associate it
with “Stability” in the plan in practice, Heijunka is a term that is associated with
production levelling. The intention of applying Heijunka is to attempt to produce a
balanced mix of production levels in products sets during a series of time periods
(Liker, 2004, Rother, 1999). To confer the plan stability, the Build-To-Schedule
(BTS) indicator tends to be associated to it. In general, plan stability is measured

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by the indicator, which compares what has been planned, what was intended to be done (the plan) and what has actually been done.

Any production system with predictable demand, which is more or less certain, and which intends to work according to the Lean Manufacturing philosophy, must have a production plan or schedule as a reference point. Nevertheless, attempts made to apply some Lean principles, such as Heijunka, tend to imply considering a unit flow of parts, and neither contemplates operational constraints, such as relevant setup times because it is assumed a preliminary high level of SMED (Shingo, 1985), adjustable labour capacity in manual posts despite being a fundamental tool of Lean Manufacturing (Baudin, 2007), nor priorities between the different batches of products to be sequenced.

This article proposes the use of an integrated production scheduling tool based on Excel and a simulator based on discrete events to solve the mix model assembly line problem of a manufacturing firm which attempts to apply Heijunka on one of its assembly lines. Given the complexity of some operational constraints, the integration between production scheduling and the simulator enables the firm to anticipate not only the impact of the plan, but also operational decisions such as human resources mobility or anticipating customers’ orders, which will be served with delays.

This article is arranged as follows: Section 2 describes the products, the production process and the supply chain of this case study. Section 3 introduces the developed tool. Finally, Section 4 presents the conclusions drawn from the case study and identifies some future research lines.

2 Problem Description

2.1 Product Description

The products manufactured by the firm are electric and electronic components, such as light switches, protection relays and surge protectors. These products are small in size and complex, thus their assembly must be very accurate.

There are numerous manufactured references, which are grouped into families, and families are grouped into ranges. For example on the line being studied, it is possible to assemble up to over 250 different references. These references belong to the set of different product families, and the latter can be grouped into products ranges. The bill of materials (BOM) for each reference is different and does not depend on the families or ranges, despite there being common components in certain cases. All the products are assembled products, so their BOMs take a type “A” structure. Some feasible product classifications can be done depending on the
product characteristics. For example, products can be classified according to the following criteria:

- Bi-polar products and tetra-polar products
- Differential chains
- Packaging

Products could even be classified depending on the strategy selected to cover demand, and two basic order types exist: (order fulfilment strategy) MTS (Make-To-Stock) and MTO (Make-To-Order). The firm deals with different loading units:

- Packaging with different capacities in the references depending on whether the product is bi-polar (6) or tetra-polar (3)
- Boxes with different capacities in the references depending on whether the product is bi-polar (54) or tetra-polar (27)
- Pallets with different capacities in the references depending on whether the product is bi-polar (432) or tetra-polar (216)

### 2.2 Process Description

The considered plant has several production lines where items are transformed, assembled and packed, and finished products are sent to its logistics centres. The plant has five assembly lines. Each assembly line is capable of manufacturing a series of references and has different work points (known as processes) where manual or automated operations are done. Apart from the different assembly lines, the plant has various U-cells (known internally as “U-Lines”) where kits are assembled, which are the raw material for some of the various assembly lines. These U-cells provide a warehouse, located on one side of an assembly line, with products.

Each process has different cycle times for the various references. Each products batch is separated by a “lure”, a fictitious part that has an electromagnetic bar code containing the “product data matrix”. Different coloured lures are placed between each batch according to the product type to be made (e.g., bi-polar or tetra-polar). In the various existing processes, there are setup times in each production batch which are sequence-dependent and known. Between each process, there are intermediate warehouses (known internally as “lungs”) and they have different capacities.

Some stages are manual, and others are completely automated; that is, they are machine-processed. Each manual stage can involve a number of operators which varies with time, some operators who can work in parallel with different processes, and thanks to operators’ training, some can change production line at any time, if required.
2.3 Supply Chain Description

The production plants of the multinational firm are distributed in four continents. Its production plant located in the province of Valencia assembles electric components. This plant has different suppliers, and is supplied by the suppliers belonging to either the Schneider group or external firms. These suppliers can be classified according to how near they are to the plant as local suppliers or non-domestic suppliers. There is also the possibility of supplying from a centralised platform (a logistic supply centre). A sketch presenting the supply chain outline is provided in Figure 1.

![Diagram showing the supply chain](image)

**Fig. 1** Diagram showing the supply chain

Having assembled and packed the different products, the plant sends deliveries to the regional distribution centres (wholesalers), which distribute to local centres (retailers) or deliver directly to some local centres if the distance is short. The end consumers then buy these products in retailers. A description of the considered supply chain topology is presented in Table 1.
**Table 1** Supply chain topology for the considered supply chain

<table>
<thead>
<tr>
<th>Functional attributes</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number and type of products procured</td>
<td>Important, 2,500 references procured</td>
</tr>
<tr>
<td>Sourcing type</td>
<td>Single (for non-domestic supplier); Multiple (for local suppliers)</td>
</tr>
<tr>
<td>Supplier lead time and reliability</td>
<td>Very short (hours) for the products supplied in JIT &amp; reliable; Short (days) for some local suppliers &amp; Reliable; Large (Months) and not reliable</td>
</tr>
<tr>
<td>Materials’ life cycle</td>
<td>Medium (6 months) before small engineering changes</td>
</tr>
<tr>
<td>Organisation of the production process</td>
<td>Mixed Model Assembly Line</td>
</tr>
<tr>
<td>Repetition of operations</td>
<td>Small batches</td>
</tr>
<tr>
<td>Changeover characteristics</td>
<td>Setup-Dependence</td>
</tr>
<tr>
<td>Bottlenecks in production</td>
<td>Mix-dependence</td>
</tr>
<tr>
<td>Working Time flexibility</td>
<td>Frequently used, additional shifts, multi-function operators</td>
</tr>
<tr>
<td>Distribution structure</td>
<td>Two or three stages</td>
</tr>
<tr>
<td>Delivery Pattern</td>
<td>Continuous LTL</td>
</tr>
<tr>
<td>Deployment of transportation means</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Availability of future demands</td>
<td>Forecasted for external demand.</td>
</tr>
<tr>
<td>Demand curve</td>
<td>Unstable, highly dependent on new product development</td>
</tr>
<tr>
<td>Products’ life cycle</td>
<td>Several months</td>
</tr>
<tr>
<td>Number of product types</td>
<td>200</td>
</tr>
<tr>
<td>Degree of customisation</td>
<td>Standard products</td>
</tr>
<tr>
<td>Bill of Material (BOM)</td>
<td>Type A and Alternative BOMS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Structural attributes</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Structure</td>
<td>Mixture</td>
</tr>
<tr>
<td>Degree of globalisation</td>
<td>International</td>
</tr>
<tr>
<td>Location of decoupling point(s)</td>
<td>Make to Stock / Make to Order</td>
</tr>
<tr>
<td>Major constraints</td>
<td>Time Dependent setup; Non-Stock capacity; Limited available capacity; Material Availability</td>
</tr>
<tr>
<td>Balance of power</td>
<td>Customer</td>
</tr>
<tr>
<td>Direction of coordination</td>
<td>Mixture</td>
</tr>
<tr>
<td>Type of information exchanged</td>
<td>Forecasts &amp; Orders</td>
</tr>
</tbody>
</table>

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(Book of Proceedings of the 7th International Conference on Industrial Engineering and Industrial Management - XVII Congreso de Ingeniería de Organización.)
3 Production Scheduling Problem

The production scheduling process consists in determining: extracting available data from the SAP; establishing levels of priorities for different production orders; determining production batches and the order (the sequence) of launching production; calculating labour resource levels.

On a daily basis, the flow manager obtains three data files from the information system, SAP® in this case:

- Customer orders data
- Production orders data
- Products stockout data in the customer’s warehouse

By means of its information system, each customer generates MTO reference orders in real time, and also informs about the consumption of MTS products. Hence at all times, the assembly line has a portfolio of demanded products and knows if a stockout occurs for any MTP products in its customers’ warehouses. In the information system, each order has a single SAP transaction number corresponding to a batch with a given reference in a certain quantity, a dispatch date and an initial dispatch date.

Should physical stockouts occur for the MTS references or orders be delayed, the order dispatch date will differ and will not have the same priority in the workshop.

In parallel and autonomously, the information system generates production orders with a batching process that differs from the customers’ orders batching process. The first step to solve the product scheduling problem consists, therefore, in relating customers’ orders to production orders, and in also allocating a priority level to each production order.

Having completed allocations and priorities, the products on the line can be sequenced in accordance with the kits’ availability at all times. Hence, the sequence (that is, the order in which each reference batch is launched in production) must consider the operation times, sequence-dependent setup times, availability and mobility of the human resources on the line, employees’ polyvalency, and the limited capacity of the different intermediate warehouses and availability of kits at all times.

4 Tool Description

Throughout the year 2012, a customised production sequencing tool has been designed. This tool has been designed with MS Excel® and with the Simio Simulation Software®.
It allows priority reports, and the analysis of poorly fitting data at both the orders and production orders level, to be generated daily. It also schedules production where the production orders on the line are sequenced in accordance with customer order priorities in order to obtain high customer service levels. This production scheduling considers: the components availability constraint, if necessary; the number of operators at each manual post on the line; the operation times in all the processes of the line; the associated setup times.

Every day, users download the three data files and copy them into an Excel spreadsheet. The Excel tool proposes different production programmes, which are based on distinct specific algorithms (by applying a pure Heijunka, by maximising the Overall Equipment Efficiency Indicator, by maximising customer service levels and the multi-objective optimisation of these objectives).

Having generated the plans, the impact that the plan has on the plant’s different relevant indicators is assessed so that stakeholders can select the solution which meets their expectations. Figure 2 provides the line layout, which was obtained with SIMIO. Moreover, Figure 3 shows the production plan generated after executing an algorithm in Excel.
5 Conclusions

This article presents the case study of a firm that manufactures electric components. It also introduces the integrated production scheduling and simulation programme tool, which has been designed and implemented into an assembly line to solve the mix model assembly line problem by considering operational constraints; e.g., production batches, mobility of human resources or sequence-dependent setup times.

As future lines of work at the practical level, the authors are currently working on extending this tool for the seven assembly lines in the production plant. Some interesting future research lines have opened up: analysing the effect that heterogeneous batch sizes have on Heijunka by considering sequence-dependent setup times; considering the polyvalency, efficiency and the mobility of human resources in an optimisation algorithm.

6 References

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