THE IMPACT OF CELL STRUCTURE ON THE MTO PRODUCTION SYSTEM

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Abstract

Today the customer market is becoming more demanding than ever. In many cases application of the 7R rule alone is not sufficient. The customer wants to have an influence on the final shape, form, functionality and features of the product. This forces entrepreneurs to abandon the make-to-stock (MTS) approach and adopt the make-to-order (MTO) concept, not only to satisfy the customer’s requirements better but also, for example, to reduce costs through manufacturing exactly the quantity of products that the market demands. The article describes an example of such an enterprise. This company is a manufacturer of windows, doors, roller shutters and other products. The custom products department manufactures products where the final look and functionality may be determined by the customer, who can take part in the process by selecting, for example, the shape, dimensions and accessories used. This is entirely make-to-order production. This system offers the benefits mentioned above, but on the other hand production planning is more difficult and the system requires a relatively high degree of production flexibility. The article describes how the application of simple methods of analysis may help to introduce a certain degree of standardisation of processes/operations/activities and to identify and eliminate certain types of waste from the production process.

Keywords: Cellular manufacturing, Make-to-Order (MTO) methods.

1 INTRODUCTION

The prerequisite to ensure customer satisfaction, which in turn allows also to maintain profitability of a production company, is the implementation of the 7R principle. At the same time, in order to remain competitive, the company naturally seeks to reduce the costs associated with the implementation of the production process. Considering the fact that the customer market is becoming increasingly demanding, it is obvious that this drive must take into account the customer’s needs, for example as regards waiting time for completion of the order, but above all in the scope of matching the product features to the expectations of the customer. The make-to-stock production system guarantees availability of a certain product range for the customer; however, if the enterprise usually manufactures a range of catalogue products which is not very diverse, it is necessary to create stocks, and the greatest problem in the context of adapting the offer to dynamic market needs is a relatively low flexibility of production processes/systems. Therefore, although it involves significantly more difficulties in the production management than the make-to-stock approach, enterprises often decide to introduce production for an individual customer, referred to as make-to-order production, for the whole assortment, or at least for a selected group of products.

The introduction of the make-to-order system for selected products (e.g. a custom products department, as in the example described in the article) can help the enterprise open new outlets for its assortment. As regards the full range of assortment, this often means a change in the company profile. Assuming that one of the enterprise’s objectives in terms of logistics is to reduce the time of the production process, which in the make-to-order system translates directly into reduced time of order completion, it is important to seek to eliminate unnecessary transport, downtime and waste generally present in the production process, and to ensure continuous product flow through the production cells. The fact that the production process of a specific product is initiated by the order placed by the customer (Figure 1) requires the application of a suction system, and therefore the manufactured quantity corresponds exactly to the market demand.

The manufactured goods may differ from each other in terms of functionality, dimensions, appearance, and design - for example as regards the components or materials used. This is typical for make-to-order production. This also requires a low level of specialisation of working positions, which must however be compensated with the high qualifications of employees who occupy them. It is unreasonable to equip the working position adapted to the make-to-order production system with advanced and expensive specialised tools if they could only be used for a small part of the assortment manufactured there. That is why custom production departments are usually equipped with all-purpose machines. Equipment on the working positions may be modest, the tools used are simple, but the machine park must be adapted to perform diverse tasks.

![Figure 1. A task performed in the MTO system.](image-url)

Diverse features of the manufactured goods do not allow for the development of a constant production cycle and require application of flexible timeframes for the process. The order completion time will be different.
depending on whether the necessary components are available right away - from storage, or whether they must be ordered, whereas the time needed for each operation may vary depending on the design of the given product. This diversity also requires a general, framework record of the production technology and technological preparation of the process for the specific group of products.[4]

Some of the indicated features of individual item production as, for example, a low level of specialisation and instrumentation on the working positions or production planning based on the order system are also mentioned in the context of non-repetitive manufacturing.[5] This is the best form of production organisation for the make-to-order production system. As indicated above, it is not possible to maintain rigid timeframes for the production of subsequent products which differ from each other, and this practically eliminates the possibility to apply the repetitive manufacturing system. It also creates a number of serious problems with the production planning.[4] In principle, no forecasts or typical production plans are prepared because the production process starts when the customer places the order and production tasks are assigned to working positions on an ongoing basis.[3]

The type and form of the production organisation also require certain limitations in terms of the selection of appropriate production layout. The non-repetitive manufacturing may assume both a direct-line and a non-direct-line form and it may be implemented in group layouts, technology-based layouts or in production lines[3,5,6].

However, the desire to maintain a continuous flow of material requires the application of a group layout.[2] Regardless of whether the production is carried out in the cells or on the production line, machines should be aligned in accordance with the order of the technology operations performed. [7,8] An example of material flow in the group layout is presented as a diagram in Figure 3.

![Figure 2. Flow in the technology-based layout.](image)

By the 1960s the most common manufacturing layouts were technology-based layouts. Groups (or whole departments) of machines of the same type were created to perform the same technology operations as, for example, groups of lathes or milling machines. Depending on the given product, it followed a specific path. The flow in the technology-based layout is presented in Figure 2. This system allows for the planning of a simple, transparent pattern for the product’s flow through the manufacturing system and, in the case of a failure, allows other machines to take over the task. However, the system requires additional transport operations to subsequent working positions, which significantly increases the time of the manufacturing process. [5,6]

The group layout assumes that the machines and equipment used in the manufacturing process should be arranged according to subsequent phases of the technological process, or that they create cells i.e. separate groups of working positions dedicated to a specific product group. Application of such solutions allows for organizing and significantly limiting internal transport at the enterprise. [7,8] This is related to the possibility of creating a line arranged according to the manufacturing technology of the given product or the production cell. However, in the event of a failure, the production process is very likely to be interrupted.

The make-to-order manufacturing system is by definition focused on the production of a wide range of goods. These are usually products with a similar overall technological process but it may vary significantly in terms of details, for example as regards the installed equipment. Each machine or device has an assigned task to perform one specific technological operation in line production, so their specialisation or process automation may be beneficial. As such, lines are used for the production of larger series and also for make-to-order production of, for example, products similar in terms of dimensions but with different equipment installed. In the production of custom goods, cellular layouts will have a wider application. [3] Production cells are divided according to the general division of the production structures. Technology cells are implemented that constitute groups of machines aligned technologically according to their function, and product cells are created, prepared for the production of a specific class/group of products. An example of a technology cell may be a lathe cell, whereas the sprocket processing cell represents a product cell. [3] Assembly cells may also be qualified to the latter of the mentioned groups.

2 A DESCRIPTION OF THE PRODUCTION PROCESS

OKNOLAST is a Polish company manufacturing PVC windows, external doors, roller shutters and other accessories available for use with windows. The production system is managed according to the MTO (make-to-order) concept i.e. it is order-driven production. The customer may select the dimensions, shape of profiles, colour and accessories (glass and anti-burglary fittings, glass with enhanced acoustic properties, roller shutters).
The basic elements which make up the final product are (figure 4):

- polyvinyl chloride (PVC) profiles that provide the structure in the form of a panel or frame,
- internal steel profiles to reinforce the structure,
- circumferential fittings i.e. elements responsible for functional properties (opening and closing, tilt),
- glass units,
- window accessories (handles, water control elements, vents etc.).

Apart from classic windows (rectangular shape), the company manufactures products with custom shapes (triangles, trapezoids, circular and oval shapes). Other than these custom shapes, the custom production department manufactures sliding windows - HST (from German: Hebe-Schiebe-Tür). HST doors are manufactured using the lift slide technology. The doors have up to 13.8 m² of glazed surface, and the lift-and-slide fittings allow their easy opening, despite the considerable dimensions: width from 1600 to 6000 mm, height from 1800 to 2600 mm. These fittings also allow for setting the window in a position for microventilation, and with electronic control - to air the rooms at specific times of the day. The manufacturer offers four types of HST doors, depending on their opening system:

- HST A - one slide leaf, one fixed leaf,
- HST D - two slide leaves,
- HST C - two fixed leaves (on the sides), two slide leaves (in the middle),
- HST C - two fixed leaves (on the sides), one slide leaf (in the middle),

The HST lift-and-slide doors are made of the following elements:

- frame assembled with screws and reinforced with an aluminium profile,
- threshold made of PVC profiles and reinforced with an aluminium profile,
- leaves made of PVC profiles welded at the corners, sliding with a roller assembly on aluminium rails.

Nearly all the components necessary to complete the order are provided by external suppliers. The only element manufactured by the company itself are glass units.

Therefore, completion of the production task according to the MTO concept requires a proper preparation of each component of the ordered HST window. Elements are technologically prepared for assembly in the processing centre. After appropriate processing (cutting, welding, milling, drilling technical holes), the elements are stored in buffers and from there they are collected for assembly.

Diagram of example of HST C window is shown in Figure 5.

Figure 5. Diagram of HST C window (max dimensions width x height : 6000 x 1600).

Figure 6 presents a general diagram for the production of HST sliding windows at Oknoplast S.A.

Currently, the assembly process is performed on five parallel working positions - five cells perform the complete assembly, which includes assembly of:

- the frame and threshold (with screws),
- the fixed leaves,
- the fixed leaves in the frame,
- the slide leaves,
- the slide leaves in the frame.

The production process ends with quality control and preparation of the ordered HST set to be shipped to the customer. Due to the large weight of the glass units, and also for safety reasons, the ready frame with leaves as well as the panes and protective strips are transported as separate freight units. Assembly of the ordered HST set is performed at its destination i.e. at the customer’s premises.

![Diagram of HST production process](image)

Figure 6. Production process diagram for HST.

Assembly of the frame, fixed and slide leaves requires a great deal of preparation and operational activities.
3 AN ANALYSIS AND STUDY OF THE PRODUCTION PROCESS

In order to improve efficiency in the HST windows assembly cells, a multi-dimensional process analysis was carried out. The analysis included:

- identification of movements performed by the employee in the course of technological operations at the working position,
- chronometry of the duration of all the performed activities.

This analysis also allowed to identify:

- the incorrect order of the performed activities,
- redundant activities,
- the fact that the duration of the same operation may depend on the operator who performs it.

As a result of a precise identification of the operators' activities during the performed processes, the following was determined assembly of:

- the frame and threshold: 29 steps,
- the fixed leaves: 16 steps,
- the fixed leaves in the frame: 8 steps,
- the slide leaves: 19 steps,
- the slide leaves in the frame: 6 steps,
- quality control and preparation of the kit for shipment: 26 steps.

For all the operations, chronometry was carried out at five assembly positions.

Assembly of an HST slide window consists of six separate phases. Table 1 and Fig. 7 present the comparison of times for particular stages of the window assembly. According to the analysis, the longest stage is assembly of the frame - it takes on average 1 h and 32 min. The shortest part of the process is installation of the slide leaf in the window - it takes approximately 10 min. The total assembly time for a window, from the time when the first part of its frame is collected until the finished HST window is put on a stand, is on average 3 h and 34 min and 47 sec (including the time for breaks).

This comparison is presented graphically in Fig. 7.

The preparation of the components for assembly is an activity which requires the employee to leave their workstation or correct the ready element. This may include, for example:

- bringing elements to the place (frame components, leaves, strips, caps, rails),
- cleaning elements and correcting them if needed,
- unpacking elements,
- measuring elements,
- additional cutting of elements.

The preparation activities take approximately 30% of the total time of window production. These are the activities which contribute most to the extended production time of the HST slide window.

A comparison of the average summary times for the preparation processes and proper assembly are presented in Table 2 and Fig. 8.

4 CONCLUSIONS

The production of slide windows at OKNOPLAST S.A. is very advanced. Thanks to the performed analysis based on the time measurement for the performance of particular activities, to eliminating operations which did not bring value to the process and to the layout change, it was possible to identify the most problematic areas where improvement can help to increase performance. On the basis of the performed analyses, it has been found that the greatest room for improvement exists in the operations pertaining to the preparation of materials. This is a part of the process which takes 30% of the total time needed to produce a window. The second area requiring
considerable room for improvement is the production system. Our calculations show that introduction of a cellular system may trigger effectiveness from 10 to as many as 14 windows per shift, which constitutes a 40% increase in effectiveness. It is worth noting that the main benefits arising from the prospective changes include faster completion of customer orders, a more flexible production process and considerable savings. The analysis of the activities within particular production stages allowed for seeing a detailed picture of the processes, and also for identifying the activities to be left unchanged (e.g. assembly), modified (e.g. the production system) and eliminated (e.g. preparation of the elements).

PROPOSED NEW SYSTEM
At the moment each employee performs all stages of production process:
- frame assembly,
- assembly of a fixed leaf,
- assembly of a fixed leaf in the frame,
- assembly of the slide leaf,
- assembly of the slide leaf in the frame,
- packing,

on one workstation.

The new production system would consist on separating tasks:
- frame assembly – two employees,
- leafs assembly (both fixed and slide) – two employees,
- assembly of a leafs in the frame and packing – one employee.

Currently, the production time of the window is 3 hours and 34 minutes. After changing the working system, the window production time would be 1 hour and 35 minutes. Thus, after the change, it is possible to increase the capacity of the production cell from 10 to 14 windows per shift.

5 ACKNOWLEDGEMENTS
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6 REFERENCES

Table 2. Percentage comparison of preparation and assembly times.

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<td>03:53:13</td>
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