ABSTRACT. The study describes the subject of allocation of products represented by one item from each product group to main company's value streams. Technological and organizational similarity is the key criterion of designing product families. In the analysis the $\alpha$ coefficient was used in order to assign each product to particular value streams. The article is a result of research in industry, aiming at creating an assortment structure in a form of product families (value streams) characteristic of lean manufacturing and to be more precise - lean management.

Key words: technological and organizational similarity, value stream, product families, lean manufacturing/production, lean management.

INTRODUCTION

These days, the "phase-thinking”, which is highly hermetic and ineffective, is becoming less and less popular. Today, production is not treated as a separated part of company but it is integrated with other company’s functions [Domański 2007, Domański, Pawlak 2007, Domański, Pawlak, 2006]. It is more and more often heard of so called value stream managers, both in theory and practice. They are responsible for complex manufacturing of certain product family (from supply sources to markets). It is very important to first set the technological route of products, which next makes it possible to group products into main product families (value streams).

ON THE WAY TO LEAN PRODUCTION

Building a production system according to the Lean Production concept is undoubtedly a long-term enterprise. The changes that must be implemented depend much on the organizational conditions of company. Key issues are [Hadaś, Cyplik 2007]: complexity of products, size and repeatability of production or the existing organization of production.
In a typical sequence of 5-stage Lean Production implementation process the analysis of value stream stage (Identify the Value Stream) is crucial for further actions. It influences both the work concentrated on achieving harmonious flow (Flow) and the possibility of logical flow control according to real market demand (Pull). The speed and amount of work of further steps of implementation of the "lean" concept depends on the quality of work within creating, i.e. separating the streams and assigning products to them. The task seems to be easy in case of a simple assortment structure with high technological similarity within each family. However, it is much more complicated in case of highly diversified assortment with many variants (technical specifications) and high variability of production plans.

The practice of analyzing a complex group of items should be based on the first and strongest premise which is technological and organizational similarity and the second one which is variability and amount of work. The second premise is yet weaker since both machines' production capacity and flexibility (substitutability) of production segments may be formed within the stream. The range of the first premise is usually more constrained, however, the practice of products standardization and periodic review of manufactured goods in order to eliminate the "untypical" ones should not be forgot.

The goal of the value stream analysis stage (Identify the Value Stream) is then (see fig. 1.):

- setting guidelines for grouping and allocating positions,
- recognition of the possibility of creating stable value streams,
- possibility of achieving synchronized flow.
Setting guidelines for grouping and allocating positions is the basic goal which is used to assign machines to particular value streams in order to build dedicated production lines or nests [Domański, Hadaś 2007, Projekt…]. Recognition of the possibility of creating stable value stream which allows for even machine load by cumulated demand for each product family is used to make economic analyses of building dedicated production units. Assigning the assortment to given streams is also supposed to facilitate achieving synchronized flow [Domański, Hadaś 2007, Layout…]. The facilitation consists in that within the "Flow" stage any additional actions apart from assigning tasks within the production plan will not be necessary. The work synchrony will result much from common features of the technological process for each item. It both prevents growing work-in-progress [Hadaś, Domański 2007] and achieving proper flow pace. As soon as the lean system reaches the "Flow" stage it will not need local stock buffers and any additional work-in-progress grow control mechanisms.

GUIDELINES FOR FORMING AND OPTIMIZING THE PRODUCTION SYSTEM STRUCTURE

Assigning products to each value stream belongs to the allocation group of problems (similarly to allocation of work stations in the production hall). When creating the value stream the product groups within the stream should be as much similar to each other as possible (technological and organizational similarity, \( \alpha \) coefficient), using the same work stations (production potential). Only then is it possible to realize the whole production process of simple product within one production unit, most often U-shaped line/nest. The issue of the work station load coefficient (its work time utilization) plays a secondary role since it is the time and task flexibility and not the capacity pressure that is the priority in lean production.

Forming value streams in lean production refers to the creation and division of production department’s law. According to the law there are two critical factors that decide about the production system structure (including i.e. what assortment should be manufactured within the accepted production system organization) [Boszko 1973]: clear work specialty and size of work within particular specialty. The first factor refers to technological and organizational similarity of manufactured assortment; the latter refers to labour intensity and work repeatability. In the article the authors concentrate on the assortment similarity issue, signalling the work size issue only.

SIMILARITY - VALUE STREAM ORGANIZATION CRITERION

The degree of similarity of two products is determined by inquiring their technological routes interference (production technology). In order to do that, a matrix \( a_{r} \) should be created. In rows there are products and in columns - work stations or homogeneous groups of work stations (JGS). The table content is binary: 1 - means that particular product is manufactured in particular work station, 0 - the opposite case. The technological and organizational coefficient is calculated based on the following formula [Mazurczak 2002]:

\[
\alpha_{i,k} = \frac{\sum_{j=1}^{r} X_{i,j} \times X_{k,j}}{\min \left( \sum_{j=1}^{r} X_{i,j}, \sum_{j=1}^{r} X_{k,j} \right)}
\]
Domański R., 2008, Technological and organizational similarity coefficient (α) as a basis for value streams in lean production. LogForum 4, 2, 3.
URL: http://www.logforum.net/vol4/issue2/no3

where:

\[
i, k = 1, 2 \ldots, i\ldots, a \quad \text{item identifier (i ≠ k)}
\]

\[
j = 1, 2 \ldots, r \quad \text{identifier of homogeneous group of work stations}
\]

\[
a \quad \text{number of assortments}
\]

\[
r \quad \text{number of homogeneous groups of work stations}
\]

\[
X_{i,j}, X_{k,j} \quad \text{technological process matrix elements calculated as follows:}
\]

\[
X_{i,j} = 0, \text{ if } m \text{ and } j = 0
\]

\[
X_{i,j} = 1, \text{ if } m \text{ and } j \geq 1
\]

\[
m_{i,j} \quad \text{number of technological operations made for item i and group of work stations j}
\]

The size of work influences the decision of allocating certain work station to certain value stream. Allocation is only justified in case of significant assortment flows since only then assigning particular work station to particular value stream causes proper work station load. The best situation is when highly similar products (α is close to 1) ensure significant work station load (however, we must remember that in the "lean" it is recommended to assume lower than maximum load in order to maintain certain flexibility).

DESCRIPTION OF ORGANIZATIONAL AND PRODUCTION CONDITIONS

An electro-installation products manufacturer is the subject of the study. The range of products is very big; nevertheless, each product is very often slightly different from the other. In order not to make the picture of the situation complicated the analysis concentrated on describing selected products - representative of each product. Such a simplification aims at avoiding detailed organizational and technological divagations. At the same time, during consultations it was stipulated that each product is slightly different from the other within the same group. Therefore, the conclusions will be true for the whole group of assortments. On the basis of production documentation reflecting the manufacturing technology of each item, 35 products - representatives - were finally selected.

ASSORTMENT GROUP ANALYSIS (BY REPRESENTATIVES)

In order to clearly identify products similarity an alfa technological and organizational coefficient was used. In short, it is an iteration procedure that consists in comparing product 1 to product 2, product 1 to product 3, etc., next product 2 to product 1, product 2 to product 3 etc., up to product 34 (last but one) is compared to product 35 (the last one). The acquired similarity rate is within <0÷1>. Zero means no similarity between products (using different, individual technology for each case; no common operations). One means that technological routes of both products are identical or the manufacturing technology of one product is fully involved in the technological route of the latter. A number ranging within (0÷1) informs about some common operations of compared products (they are manufactured on the same work station - machine). The closer to 1, the closer the relationship.

The generated technological and organizational similarity α matrix, which is presented below, is prepared as assortment (rows) - assortment (columns) - a-a matrix.
SEPARATING PRODUCT GROUPS (FAMILIES) OUT OF SET OF ASSORTMENTS

Acquired technological and organizational similarity values are the basis for conclusions about the quantity and number of value streams. The general rule is to look for possibilities of assigning products to certain set (product family) as close to the diagonal (line X) as possible. The bigger the distance from the diagonal, the lower the similarity of compared products.

The beginning and end of the alfa matrix can be clearly interpreted. The products with numbers from 1 to 6 are characterized by high similarity, over 0,80, except from the relation between products 1 and 6, which is 0,73. Grouping them into one subset does not raise any doubts and the lower similarity of products 1-6 (too high anyway) may be neglected.

There is a similar situation at the end of the alfa matrix. Products 33-35 are also characterized by close technological and organizational similarity. Only the relation between products 34-35 deviates slightly and it is 0,75. All products with numbers 33-35 represent electronic devices, so they should be grouped in the same product family (despite low, but still significant similarity, product 33 is included to the group due to specific technology of one of operations).

Products 31 and 32 are characterized by decidedly lower similarity to the previously distinguished group. It is 0,60. There are no products with similar parameter in the vicinity. That is why the decision about setting a product family of 2 products was taken.

The situation is not so simple in case of the a-a matrix. In this case the approach of having various solution variants (scenarios) is the most appropriate one. It is proposed to create one set out of the remaining products - items from 7 to 30. However, such a conglomerate is characterized by a big number of components - 23 items and the technological and organizational similarity is harmonious, decreasing much at the ends of the diagonal which is perpendicular to diagonal X. Nevertheless, even smaller product groups, closer to each other (alfa parameter optimization) should be looked for within this set.

Variant analysis shows further division possibilities. There is a big similarity between products from 7 to 18. Next, there is another subset of products from 19 - 22. However, a closer analysis of the manufacturing technology (assortment-work stations matrix, not described in the article) shows that...
the alfa similarity should be corrected with work station groups review (machine park). The technology of item 18 corresponds with both the first and second subgroup (at the end of the production cycle). Therefore, due to "family" connections product 18 should be assigned to the second subset. Thus, the first set involves items 7-17 and the second one - products 18 - 22.

The other products, from 23 to 30, form the last set. Product 30 from the group, with high alfa parameter is noticeable. It corresponds significantly with the beginning of the described set and its location is caused by the source data file structure. The family is much differentiated. It contains almost identical products as well as only half-similar ones (positions 25 - 29), deviating much in terms of the manufacturing technology similarity.

**FORMING VALUE STREAMS WITHIN PRODUCT GROUPS**

The final step of the allocation is assigning each product group (family) to main (key) value streams in company. Apart from the technological process system, the assortment structure - mainly quantity proportions and the perspective of their change were taken into account.

It was decided to select 3 main value streams of the company:
- connecting devices production stream - 4 product families, 30 representatives,
- delimiter value stream - 2 product families, 2 representatives,
- measuring devices value stream - 3 product families, 3 representatives.

In the current situation a "strength distribution" within the assortment may be done. According to the 80/20 rule - a big part of production stream is generated by a small number of products. At the macro level the connecting (51%) and measuring (42%) devices play the main role in the assortment quantity structure. The delimiters account only for 6% of company's production (niche). At the micro level, family A (half of the value stream) predominates within the connecting devices stream, whereas, in case of the measuring devices and delimiters families G, H and F are the leaders. The acquired configuration of value streams is adequate to the current situation of the company. According to the company's development vision for the next few years it is planned to increase production of connecting and measuring devices proportionally. In case of delimiters production the "niche" has been investigated. The conclusion is that the market is not saturated, which resulted in tripling their production in the analyzed time horizon.

**Table 2. Product groups and value streams matrix**

<table>
<thead>
<tr>
<th>Connecting Devices Stream</th>
<th>Delimeter Stream</th>
<th>Measuring Devices Stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

Source: own study
SUMMARY

To sum up the discussion about forming value streams in the process of building the lean production system it must be clearly stated that it is a multi-aspect issue. The above-described case study shows that actions based on technological and organizational similarity are very subtle.

Appropriate practice of forming value streams allows to avoid many detailed problems in further work on creating the Lean Production system. The main are: difficulty in achieving a stable value stream and in building synchronous manufacturing. The management practice shows that the issue is more complex than it is presented in theoretical studies. In particular, the issue is difficult in the face of constrained budget for buying machines and auxiliary devices. There occurs another constraint which makes competitive value streams use the same resources.

REFERENCES


WSPÓŁCZYNNIK PODOBIEŃSTWA TECHNOLOGICZNO – ORGANIZACYJNEGO (\(\alpha\)) PODSTAWĄ KSZTAŁTOWANIA STRUMIENI WARTOŚCI W SZCZUPŁEJ PRODUKCJI

STRESZCZENIE. Opracowanie podejmuje tematykę alokacji poszczególnych wyrobów, reprezentowanych przez przedstawiciela danej grupy (de facto grup wyrobów) do głównych strumieni wartości przedsiębiorstwa. Głównym kryterium projektowania rodzin wyrobów jest podobieństwo technologiczno - organizacyjne wyrobów. W procesie analizy posłużono się współczynnikiem \(\alpha\), na podstawie którego, decydowano o przydziale poszczególnych wyrobów do odpowiednich strumieni wartości. Artykuł jest wynikiem prac badawczych prowadzonych w przemyśle, nakierowanych na stworzenie struktury asortymentu utrzymanego w konwencji rodzin wyrobów (strumieni wartości), charakterystycznych dla podejścia szczupłego wytwarzania, a szerzej konstatując szczupłego zarządzania (lean management).

Słowa kluczowe: podobieństwo technologiczno-organizacyjne, strumień wartości, rodziny wyrobów, szczuple wytwarzanie/produkcja (lean manufacturing/production), szczuple zarządzanie (lean management).

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