IDENTIFICATION OF LEAN FEATURES IN THE DESIGN OF THE MANUFACTURING UNIT

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Abstract

The subject of interest of hereby article is the identification of features related to "the leanness" of production units. In the context of the above, research was undertaken, the main purpose of which was to verify wide list of features which are available in many publications. To achieve this purpose, surveys were conducted among Lean Production experts. The research allowed the authors to define the managers’ preference for features of "the leanness" of production units and they significance. On the basis of managers’ preferences, KPIs were also selected, to assess preferred features of "the leanness". The rank of this KPIs may be the basis for the evaluation of lean production units project variants (using analytic hierarchy process (AHP) method).

Keywords:
Production unit, features of leanness, Lean Production

1 INTRODUCTION

The structure of a production system can be shaped and it can be considered as a combination of workstations linked to a technological process, with the optimization of those relationships, or as a grouping of details to be made within production units [12]. It should be confirmed by an analysis of organizational and production conditions.

Among the production conditions, three factors are most important: the range of items (production programs, the number of items and their complexity, technological and organizational similarity, manufacturing periods), production technology (technological routes of details) and production capacity (quantitative and qualitative structure and production process tooling) [2].

Production unit is a type of organizational unit, which is a team of people equipped with means of work, capable of acting independently to implement the particular program. The smallest unit capable of self-operation is the workstation, while the elementary process for this station is an operation. Workstations work together in the production process within complex organizational units [16].

Production unit are characterized by a large variety of forms. The occurrence of this diversity is related to many classification criteria [5]:

- Complexity of the production unit - from production cell of 0 degree of complexity - workstation, to cell of 4th degree of complexity - department,
- Method of material flow between workstations (lines, cells),
- Control of the work of these units with fixed allocation of operation to workstation (controlled by schedule ) or no strict allocation (eg according to FIFO rules),

On the other hand, criteria to separate and develop appropriate forms of production units are common and can be distinguished as follows [5]:

- Maximize the utilization of production capacity in each production unit,
- From production cell of 0 degree of complexity - workstation, to cell of 4th degree of complexity - department, maximize the similarity of elements and processes to be executed in an individual unit,
- Minimize the size of product range manufactured in a given production cell,
- Minimize the amount of diversity in the production units i.e. the quantity of machines and equipment,
- Close the manufacturing process i.e., limit cooperation between production units and aim to carry out each assortment in one cell.

The superior criterion is to maximize the use of the production capacity of each unit [6].

As regards production configurations are mostly divided into manufacturing cell or lines. Both forms of the production structure can exist as technological and material ones. There are also hybrid forms of production structure, and they can include elements that have the characteristics of all aforementioned forms.

In linear form of production structure, the flow of material is essentially unidirectional and stable, and subsequent positions and production units are arranged in the sequence resulting from routing i.e. the order of the individual technological phases and operations.

Whereas cells have workstations set according to the criterion of minimizing the transport work between them. Usually, the flow of materials is organized as regular within the individual cell. However, it is irregular between different cells [8].

2 CONDITIONS FOR SELECTION AN ORGANIZATIONAL STRUCTURE FOR MANUFACTURING UNIT

J. Boszko states that development of manufacturing units depend on two parallel factors: the clearly specified specialization of works and the size of works in a given specialty [1]. The first of these factors describes the technological-organizational similarity of manufactured products, and the other refers to the repetition of work and labour.

Sometimes there is a problem to choose the form of production organization for similar conditions or incompatibility of one from three following parameters [13]:

- coefficient of technological-organizational similarity (ρwr),

\[ \rho_{wr} = \frac{\sum_{i=1}^{m} \frac{a_i}{r_i}}{\sum_{i=1}^{m} \frac{a_i}{r_i}} \]  

The research was undertaken to verify wide list of features which are available in many publications. To achieve this purpose, surveys were conducted among Lean Production experts. The research allowed the authors to define the managers’ preference for features of "the leanness" of production units and they significance. On the basis of managers’ preferences, KPIs were also selected, to assess preferred features of "the leanness". The rank of this KPIs may be the basis for the evaluation of lean production units project variants (using analytic hierarchy process (AHP) method).
where: m – number of operations (generic) in given production route for item,
\( r_i \) – number of homogenous workstation groups (HWG) in whole production unit
a – number of items in the assortment in production unit

This coefficient can be calculated for each item and will illustrate how selected HWG agrees with the route of given item. It defines an average similarity of items in terms of technology and organization within item group (manufacturing unit)

- Average load capacity of the operations \( f_{opt} \) i.e. degree of workstation load through operations

\[
 r_{op} = \frac{\sum_{i=1}^{m} r_{opt}}{m_{cz}} \tag{2}
\]

where:
\( r_{opt} \) = i \( p \) load capacity of i operation
\( m_{cz} \) – the number of operations in item routing

the formula on load capacity \( r_{op} \) determines that the stabilization\(^1\) of production depends on the amount of labor intensity and production rate. Therefore, each operation creates other conditions to arrange the production.

- The coefficient of variation of works (f)

\[
 f = \frac{m}{r} \tag{3}
\]

Where: m – the number of operations
r – the number of workstations

Herein coefficient shows the average number of operations performed at workstations.

Above mentioned coefficients of production stabilization \( f_{opt} \) and f i.e. the quantity of single operations steps to be executed at workstation are classification criteria in order to arrange the production and optimize the structure of production systems.

According to J. Boszko [1] the range of products for straight-line production units is 3-12 and for production lines 1-5. The groups of items must guarantee a high technological and organizational similarity of items and a high stability of production at whole workstations.

Analysis of the value of individual parameters is the basis to choose an organizational form of the production unit. When the parameters of production stabilization and organizational and technological similarity are known we can determine an optimal structure for production organization.

Such classification is an indispensable tool for the design and upgrade of production system structures as well as existing production systems. Apart from the similarities between technology and organization, the aspects of logistic orientation of the production process to customer service are increasingly chosen for the organization of production [11].

The instance of aforementioned relation is the Lean Production concept, aimed at shortening production cycles and eliminating inventory.

3 “LEAN” PRODUCTION UNITS

The primary feature of Lean Production is the production of standard products for the market, which are produced in optimized design and manufacturing processes by means of specialized equipment.

The “lean” production system is usually organized according to the Just in Time concept.

Material flow in production line is one-way and the positions are set in the order of the technological process and taking into account the principles of saving the production area.

The feature of lean production is a detailed and optimal design of value streams. In this situation, attention must be focused on their appropriate structure i.e. production system must be based on Just in time concept (zero inventories). Development of the structure of production system consists in seeking the best configuration of value streams [7].

According to the Lean concept one should create flexible item oriented resolutions of the organization of a production process (value streams) [4] [18]. Apart from that the structure of the production system according to principles of herein concept is a long-lasting task set to the process of improving. The scope of changes which must be made depends to a large extent on organizational conditions of the enterprise.

It depends to a great extent on the complexity of the items that are manufactured, the volume and reproducibility of production, and in particular on the resources of the production and their characteristics.

One of essential decisions is to classify items to value streams. By creating a stream of values, the groups of products that make up its composition are closely matched (coefficient of technological-organizational similarity \( p_{cz} \)). They utilize the same workstations (production capability).

Then it is possible to perform the entire production process of a single product within a single production unit, most often a U-shaped line [2] [3]. However, because the Lean concept is associated with many features of “leaness” in the design process of the production unit, their relevance and advisability should be considered.

4 VERIFICATION OF LEAN FEATURES IN THE CONTEXT OF THE DESIGN OF PRODUCTION UNITS

4.1 Identification of lean features

Based on literature study and brainstorming authors define the list of 48 features indispensable for „lean“ production unit.

These features are classified into 6 groups:

- Organization of production units,
- Execution of manufacturing processes,
- Inventory management in production system,
- Human resource management,
- Administrative processes,
- Others.

In the expert opinion survey were considered the four groups of attributes concerning directly the production units (administrative processes and others were discounted).

4.2 Research of expert group

From the point of view of the nature of data obtained, this is a qualitative research, due to the limited sample. For this reason, the results obtained explain and understand the phenomena analyzed, but they cannot be statistically confirmed. Undoubtedly they characterize the

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\(^1\) The number of operations aimed to the workstation is a measure of production stabilization and symptom of narrowing of production unit specialization.
surveyed population. Prior to the main study, a pilot study was carried out to verify the appropriateness of the research procedure chosen: the selection of subjects, the adopted variable indicators as well as the research tools used.

In order to reach the Lean Management experts, the survey questionnaire was sent electronically via e-mail. Each study was preceded by a telephone conversation explaining the purpose of the study and only after the respondent’s acceptance was sent questionnaires surveyed. The study has non random character. Thirty one experts from all over Poland participated in the study, who met the criteria of: competence level, work experience and position.

The main reason for the nonrandomization of the sample is the existence of boundary constraints. These are among others an access to Lean experts and their consent to fill the questionnaire form.

Since the main purpose of the research was to identify key features of a lean manufacturing unit, the basic question was: Please evaluate the significance of the individual factors determining the leanness of a manufacturing company’s production unit for the organization of production units.

Respondents indicated the importance of these factors on a scale of 1 (completely irrelevant) to 5 (very important, important).

The highest rated factors for the organization of the lean production unit (weighted average and ranks 4 and 5) are presented in Table 1 below.

Table 1. The evaluation of the highest rated factors determining the leanness of a production unit for the organization of production processes.

<table>
<thead>
<tr>
<th>No</th>
<th>Features</th>
<th>Level of organisation</th>
<th>Weighted average</th>
<th>Rank 4 and 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Organization of workstation (eg. 5S or others job improvement techniques)</td>
<td>Single workplace</td>
<td>32.5</td>
<td>77.4%</td>
</tr>
<tr>
<td>9</td>
<td>Reduce the setup times (eg. SMED)</td>
<td>Single workplace</td>
<td>31.5</td>
<td>74.2%</td>
</tr>
<tr>
<td>10</td>
<td>Improve the value added index (percentage of share of working time to waiting time for processing) (74%).</td>
<td>Value stream</td>
<td>31.25</td>
<td>74.2%</td>
</tr>
</tbody>
</table>

From 31 surveyed experts 22 indicated that it was very important to minimize the length of the production cycle. Thus, respondents consider this to be a very important feature of leanness, which significantly influences the minimizing the operating costs of production units. The level of organization associated with the value stream is important when production units are designed at the stage of joining machines into groups. It is important to pay attention first to the features that apply to it.

Survey also had a question to assess the significance of the individual factors determining the leanness of the manufacturing plant's production unit to conduct production processes. The highest average rating received two following factors (figure 1):

- Increase productivity (ratio of quantity produced to quantity of input resources used),
- Processes - focus on a product flow (resource management, machines according to the routing).

Figure 1. The evaluation of the importance of factors: increasing the productivity and focus on material flow as determinants of lean production unit. Source: Own study based on the research

Another question refers to assessment of the significance of the individual factors determining the leanness of a manufacturing company’s production regarding inventory management.

The highest average weighted value received two following features (figure 2):

- Minimize an average stock of final products,
- Minimize an average work in process.
The last question that ended up evaluating the significance of the individual characteristics of the "leanness" of the production unit was about the features the respondent considered crucial in the assessment of the company's lean production unit.

In the survey six features were proposed:

- Average load of machines,
- Number of machines and devices involved in the production process,
- The length of production cycle (Lead Time),
- Average work in process (WIP),
- Value added indicator,
- Average stock of final products.

Interestingly, only 5 from the 31 surveyed experts has indicated that the number of machines and equipment was very significant and only 3 indicated the same importance regarding the average machine load (figure 3). Analysis shows that although measures are important, they are not indicated as key ones. However four remaining indicators are crucial in the measurement of functioning in order to achieve lean production unit and include as follows:

- The length of production cycle (Lead Time),
- Value added indicator (percentage share of working time until waiting for processing),
- Average work in process (WIP),
- Average stock of final products.

5 GUIDELINES FOR THE DESIGN OF LEAN PRODUCTION UNIT IN CONDITIONS OF LIMITED TECHNOLOGICAL AND ORGANIZATIONAL SIMILARITY

In lean production there is a linear type of flow in which the technological similarity is as follows: similarity features—different items that work in principle on the same HWG, identical routing, similar proportions of labor intensity; technological and organizational similarity $\rho_tr = 0.85-1$; stabilization i.e. coefficient of variation of works $\tau > 1.5$ and average load capacity of the operations $f_{capr} = 0.2-0.5$ [14]. For such organizational conditions, the subject of design is a production line with variable load. Production unit in the form of the line due to its organizational conditions meets the experts' preference for "leaness".

The situation becomes complicated in organizational conditions worse than recommended for the production
line. When technological and organizational similarity of items is lower than 0.85 production unit is type of Cellular manufacturing with looping of details. It is a item-specialized unit but the layout of the machine does not coincide with the route of all details.

Unit of this type does not meet all features of leanness in accordance with defined ranks. This fact is why in the subsequent work the authors undertake the topic of designing an alternative form of a production unit (that fulfills with a higher degree the features of leanness)

Identified lean features including their ranks shall be exhibited by means of KPI that assess the production unit. Based on experts’ opinions following KPIs were adopted (table 2).

<table>
<thead>
<tr>
<th>No</th>
<th>Selected measures</th>
<th>Traditional</th>
<th>Lean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The number of machines and equipment involved in production process</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Average load of machines</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>The length of production cycle (Lead Time)</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Average work in process (WIP)</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Value-added indicator</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Average stock of final products</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

The first two indicators: the minimization of machinery and equipment and loading of machines are characterized by traditional design units. Whereas the remaining 4 refer to lean production units.

Further improvements to the lean production design will consist in introducing and broadening the use of Lean Management tools.

SMED is one of many methods of lean production which aims at lowering the amount of waste in manufacturing process. SMED provides fast and effective setup method (transformation of manufacturing process) from the present to a different one. Fast setup is here the key to reduction of the size of manufacturing batches and at the same time to improvement of material flow [19].

Fast equipment setup in a machine on production line is the key precondition to increase the flexibility of the production. Methodology of SMED (Single Minute Exchange of Die) is an example which allows reducing the time of setup practically to the minimum [10].

The main idea of the continuous improvement is about the fact that the majority of members of every organization discover possibilities of improvement of processes, in which they take part; they find and put into practice solutions serving the increase of productivity and quality of operations and products. [17], [9].

Lean production unit being subject of herein study shall be improved in order to enhance a continuous flow. In addition, the complexity of the activities means that the chain of various activities aimed at "lean management of organization" should never terminate or wrap up [15].

It is extremely important in the implementation of the process approach, which in this case is personalized in Lean Management concept, to be aware of necessary changes and be willing to initiate them. It is most of all the management that should know about benefits resulting from using this type of concept, in order to involve their staff in gradual improvement of processes [17].

6 CONCLUSIONS

The research findings confirm that a broad spectrum of lean features of the production unit has been correctly identified. None of the experts stated that these factors were wrongly indicated.

Nevertheless, their assessment of the importance of individual features is the basis to adjust preferred features of a lean production unit under conditions of limited technological and organizational similarity.

The resulting KPI values should support the decision making in the scope of selecting an appropriate structure of the production unit.

The results obtained are the guideline for the development of the design methodology of the production unit, and in particular the allocation of operations to workstations, load balancing, site development plan.

7 ACKNOWLEDGMENTS

8 REFERENCES


