DESIGN OF PRODUCT SEGMENTATION IN ASSEMBLYLINE

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The paper deals with the products segmentation that is a flexible way of grouping products and simplifies both campaign planning as well as the creation of condition records in trade promotion management.Capacity channels, which are created by segmentation, increases seriality of assembly processes in customised production (Make to Order/Engineer to Order - MTO/ETO). These advantages enhance the competitiveness of the company in terms of cost reduction, acceleration and improvement with product quality increasing.In addition, the paper discusses the procedure how to segment products according of operational time.

KEYWORDS

adaptive assembly processes, segmentation of products,development trends, advanced industrial engineering, production strategy

1 INTRODUCTION

The adaptive assembly has, for example, very close to the intelligent product. The assembly can be adapted to production and material requirements of the product. The system can be adapted to the production (ideal quickly). The adaptive assembly allows changing the production operations, or the parameters (product size, roughness etc.).[Durica 2015]

This research question is based on the hypothesis:

- ***Hypothesis:*** What happens if we try to segment products instead of components and assembly operations instead of machinery? In addition according their operational time?

This paper is structured in the form of four main sections, where are demonstrated concepts contributing to the development of segmentation in production and assembly line, because segmentation is fostered by the search of cost minimisation. In section 2 a literature survey is presented for supporting the analysis of group technology and their achievements in production.In section 3 a detailed explanation of the problem is given. In section 4 our method for segmentation of productinproduction system is proposed and the required tools are described.Section 5 reports the case study of segmentation of product line in manufacturing enterprise.Finally, a short summary and an outlook are given in the conclusion (section 6).

2 LITERATURE SURVEY

Group Technology (GT)is a manufacturing philosophy in which the parts having similarities (geometry, manufacturing process and/or function) are grouped together to achieve higher level of integration between the design and manufacturing functions of a enterprise.

The group of similar parts is known as part family and the group of machineries used to process an individual part family is known as machine cell.

It is not necessary for each part of a part family to be processed by every machine of corresponding machine cell. This type of manufacturing in which a part family is produced by a machine cell is known as cellular manufacturing. The manufacturing efficiencies are generally increased by employing GT because the required operations may be confined to only a small cell and thus avoiding the need for transportation of in-process parts.

Group technology benefits manufacturing in many ways. Itreduces the number and variety of parts. Process planning for the remaining parts is easier and moreconsistent.Computer Aided Process Planning (CAPP) is an important tool for this. It uses the coded similarities to plan consistently, standardize and accurately estimate costs.It then assigns the part to a GT manufacturing cell.Group Technology cells reduce throughput time and Work-In-Process. They simplify schedules, reduce transportation and ease supervision.The other achievements of group technology – examples of areas what can increase vs. what can reduce GT are shown in Fig. 1.

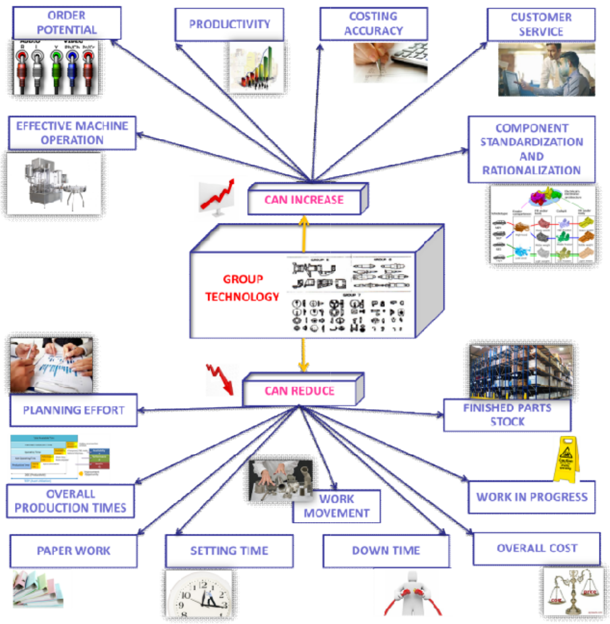

Figure 1. The achievements of group technology

Intuitive grouping is the simplest and most common method of creating part families. Experienced engineers and shop people examine the product mix and separate products and parts into processing families. These part families become the basis for workcells.

When there are more than about 100 parts and more than a dozen or so processes, Production Flow Analysis (PFA) or Coding and Classification is indicated.

3 PROBLEM DEFINITION

We can realize segmentation of production, when we analyse the process structure and the product structure.Existing methods of segmentation products not taken into account the third dimension, such factors differentiating operating times, failure to use this option may result in a slowdown of throughput of the assembly line, increase WIP and increase productivity wastes.Segmentation of production is shown in Fig. 2.

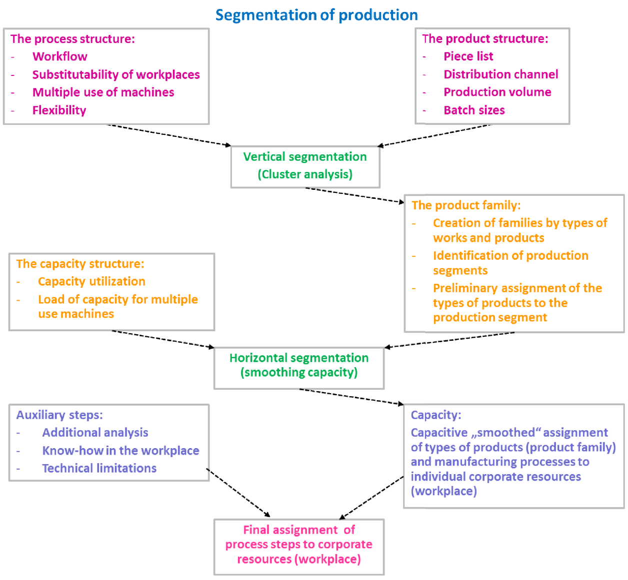

Figure 2. Segmentation of production[Krajcovic 2016]

The results of the segmentation of production are:

- cellular layout (Fig. 3) - machines 1,6,7,9 and 10 are duplicated in multiple cells,
- hybrid layout – for example cellular layout with the change in orientation of cells (Fig. 4).

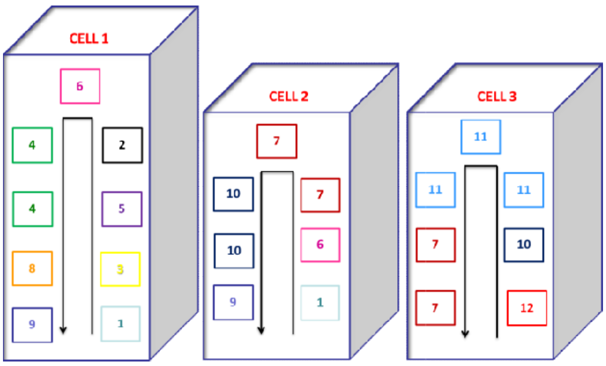

Figure 3. The cellular layout

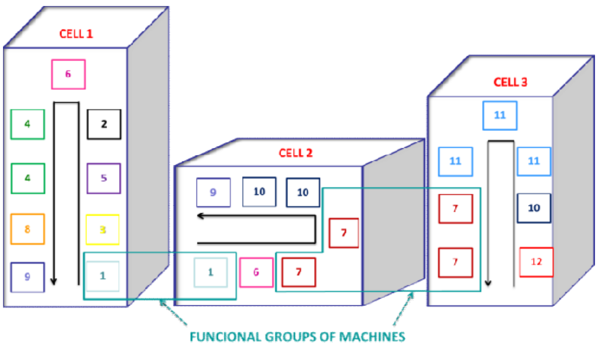

Figure 4. The hybrid layout

4 DESIGN METHOD

4.1 *The segmentation of products*

Fig. 5 shows the state before and after the implementation of segmentation - three clusters of products (families of products), which have common operations (process steps).

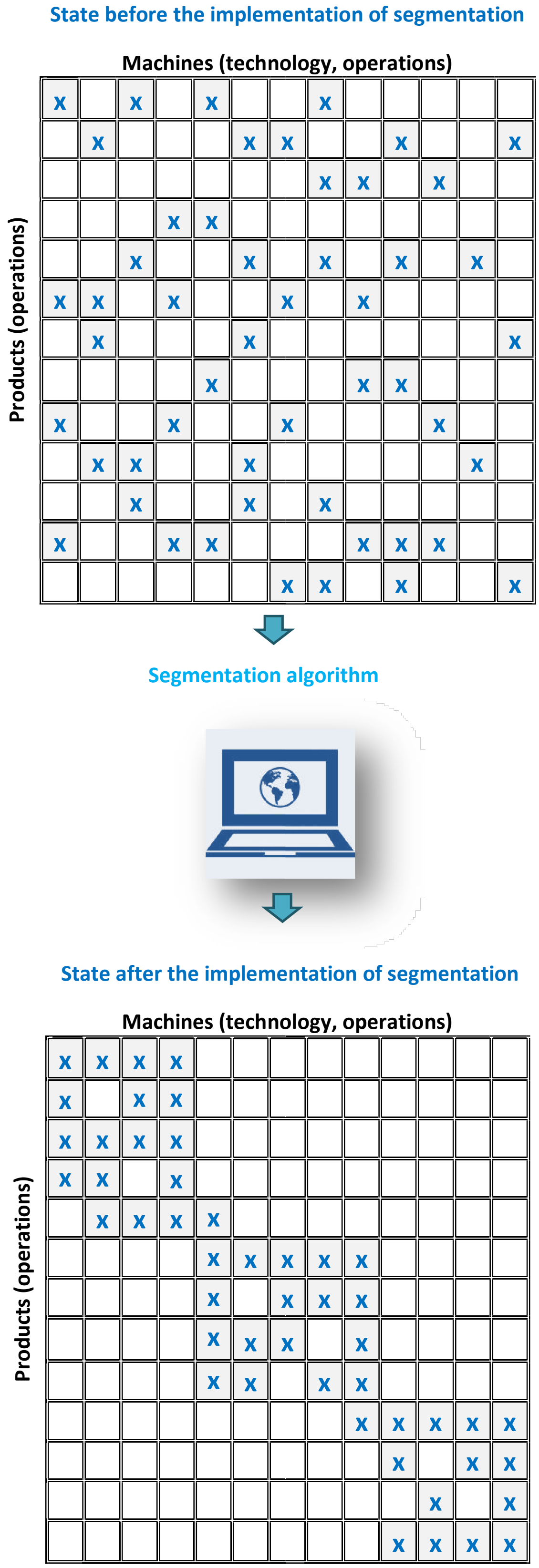

Figure 5. Flow of segmentation of products[Lieskovsky 2016]

Production tasks are performed in the so-called autonomous cellular structures of production processes that integrate information and material flows. Product groups clustered on the principle of group technology are implemented in manufacturing cell or assembly line.

Based on the application of methodologies and product segmentation it can be applied choice of an optimal design solution of the dimensional structure (layout) such as:

- manufacturing cells - as part of a larger process or production line,
- autonomous cell production - as an independent autonomous unit production system,
- assembly line - as one of several segmented assembly lines of production system (add-supplement of writer).

According to professorGregor [Gregor 2015] the number of variants has a great impact on overall costs. Growth in the number of variants is increasing in steps particularly the cost of the selection of new suppliers. Mastering the task of variation is:

- segmentation, or delaying the formation of product differentiation toward the final assembly (automotive industry).

The benefits of segmentation are:

1. uses the principle of group technology,
2. establishes and improves capacity channels,
3. increases seriality of products.

Two basic forms of segmentation are distinguished:

- Vertical Segmentation - types of products (volume, type of product, the structure of sales).
- Horizontal segmentation - by processes (optimization of material flow, smoothing capabilities, technological conditions).

There are several algorithms for creating segmentation:

- Analysis of production flow - PFA (Production Flow Analysis) developed J.L.Burbridge (1971). PFA uses a matrix of part numbers and machine numbers to group families. Columns represent the machines whose numbers and names are at the top.

Rows represent parts whose numbers and names are on the left. When a particular partrequires a particular machine, the operation sequence number is in the intersectingspreadsheet cell. Sometimes, merely an "X" signifies that a particular part needs aparticular machine.

- SLCA (Single Linkage Clustering Algorithm), CLCA (Complete Linkage Clustering Algorithm), ALCA (Average linkage clustering Algorithm).
- ROC (Rank Order Clustering) - algorithm binary arrangement of components in the matrix.

Similarity coefficients represent the shortest distance equivalent to assess the similarity of objects are generally used to compare the similarity of two objects (for example, two products) based on the number of common resp. different characters. There are several types of calculations as:

- Jaccard similarity coefficient:

$$Kp = \frac{a}{a+b+c} \tag{1}$$

- Sorenson similarity coefficient:

$$Kp = \frac{2a}{2a+b+c} \tag{2}$$

The following applies:
a - the number of common features into two objects,
b - the number of features of object 1 that are not present in the object 2,
c - the number of features of object 2 that are not present in the object 1,
d - number of characters that are not present in the object 1 nor in the object 2.

Segmentation of products and its methodology can be expressed in 5 points:

1. Build the matrix: Products - Technology (types – assembly operations).
2. Calculation of similarities (e.g. Jaccard coefficient) for each pair of products (for SLCA, CLCA and ALCA algorithms) or by an algorithm of binary arrangement of components in the matrix (the ROC).
3. Adjustment similarity matrix according to the principles of the method chosen.
4. The gradual grouping products into clusters (family or segments).
5. Graphical representation - dendogram or final matrix.

Segmentation is further used in an environment design assembly processes. The basic design phases of the new or to be improved assembly process are:

1. Analysis of the inputs (P, Q, R, S, T, segmentation of products, etc.).
2. Proposed structure assembly (manual, mechanical, etc.).
3. Draft the term structure (sequence of operations, performance standard installation).
4. Proposal of the spatial structure (layout distribution).
5. Target requirements.
6. Project implementation and deployment.

Note:
P (product),
Q (quantity),
R (routing) - technological procedures,
S (service) - technological equipment,
T (time) - operating time.

Segmentation allows creating segments of products according to the occurrence and occupancy technological steps. Attention: Individual segments of products do not reflect duration of assembly operations and diversity. There are more solutions how to split down the assembly operations and determine how to plan. These solutions relate to the possibilities of a particular assembly process or product characteristics.

At high of variation of products and variation of assembly operations (where it is not possible to make any solution above) represent high opportunity for forming a queue in front of the downstream operations, which will increase work in process (products waiting in assembly line) and reduce the flow through the process.

The mentioned facts suggest that the segmentation of products extended by another dimension (for example - the length of time of assembly operations) can be performed as additional step that will ensure the distribution of products which can be scheduled without additional modifications of the assembly process and assembly operations.

5 CASE STUDY

5.1 Segmentation of product line in manufacturing enterprise

Understanding manufacturing strategies (environments) and differences between them affect company results and customer satisfaction. Nowadays companies are doing all the activities to achieve the shortest possible lead time for order entry and delivery of finish goods on time. [Lieskovsky2014].

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Ensure all customer requirements have resulted in high variability of products. The assembly line must be designed to produce products with a wide variation of operating times and a number of assembly operations. The products have differences from 8,0hrs to 23,0 of operating time and from 5 to 8 assembly operations. In the production there are three segmented lines where the planning system could order any products after advance segmentation because each line is managed for certain family of products with comparable operating times and assembly operations. What is more exceptional: these segmented products could order planning system anytime the material for the start is available.

Figure 6. Segmentation of product line (Emerson)[Lieskovsky 2016]

5.2 Advance segmentation of products

Here is simple procedure how to segment products according of operational time. Below is a table of family products after segmentation (Fig.7). The table contains 10 products with 7 assembly operations included. The simple steps:

1. Identify max and min values of the duration of operations (from AO 1 to AO11).
2. Calculate the difference and average between the max and min values per each assembly operation across the products.
3. Identify priorities for advance segmentation according differences (priority determines the sequence of segmentation, for example. Priority 1 = getting started segment of AO1)
4. Use 1 of n priorities according how big differences are between max and min, and according to number of assembly lines, where the segmented products will be placed.
5. Determining the range of the categories:
   - AO2, AO7, AO 9 and AO11 have priority of segmentation 0 – into all boxes insert number 1.
   - AO1 has priority number 1: to 0,6 (AVG) insert number 1; over 0,6 insert number 2.
   - AO4 has priority number 2: to 0,8 (AVG) insert number 1; over 0,8 insert number 2.
   - AO6 has priority number 3: to 4,9 (AVG) insert number 1; over 4,9 insert number 2. (see Fig. 8)
6. Sort largest to smallest in the order to: the first by AO1, the second by AO4 and the last according AO6.
7. This allows sort products according AO6 by the end - as by operation with a high priority and a maximum difference in length of assembly operation.

After advance segmentation substitute instead of characters 1 and 2 the real operating times so we get the result (see Fig.9 and Fig. 10).

Where:

AO1-AO11 – Assemblyoperations
A-N – Products
Max – Maximum value of duration of operation
Min - Minimum value of duration of operation
Sum – Sum of time of assemblyoperation
Avg – Average between the max and min
Diff – Difference between the max and min
Prio - Priority

Product / Operation	A	C	D	F	H	I	J	K	L	N	Max	Min	Avg	Diff	Prio
AO1	0,7	0,0	0,4	1,2	0,8	0,9	1,2	1,2	0,8	0,7	1,2	0,0	0,6	**1,2**	**1**
AO2	1,5	1,7	1,4	2,1	2,2	1,3	1,0	2,1	2,2	2,0	2,2	1,3	1,8	**0,9**	0
AO4	2,0	1,0	2,2	2,5	1,5	1,5	1,7	2,5	1,5	2,0	2,5	1,0	1,8	**1,5**	**2**
AO6	5,7	2,5	3,7	6,8	3,1	4,2	3,1	7,3	2,5	5,7	7,3	2,5	4,9	**4,8**	**3**
AO7	0,0	0,3	0,2	0,3	0,3	0,0	1,1	0,2	0,3	0,2	0,8	0,0	0,4	**0,8**	0
AO9	1,4	1,6	1,1	1,5	1,7	1,6	1,4	1,5	1,6	1,1	1,7	1,1	1,4	**0,6**	0
A11	0,3	0,4	0,2	0,9	0,3	0,4	0,2	0,8	0,4	0,2	0,9	0,2	0,6	**0,7**	0
Sum	**11,6**	**7,5**	**9,2**	**15,3**	**9,1**	**9,9**	**9,6**	**15,6**	**9,3**	**11,9**					

Figure 7. Family of products after segmentation with an additional calculation

Product / Operation	A	C	D	F	H	I	J	K	L	N
AO1	**2**	1	1	**2**	**2**	**2**	**2**	**2**	**2**	**2**
AO2	1	1	1	1	1	1	1	1	1	1
AO4	**2**	1	**2**	**2**	1	1	**2**	2	1	**2**
AO6	**2**	1	1	**2**	1	1	1	2	1	**2**
AO7	1	1	1	1	1	1	1	1	1	1
AO9	1	1	1	1	1	1	1	1	1	1
A11	1	1	1	1	1	1	1	1	1	1

Figure 8. The same family of products but with numbers 1 and 2 placed instead of operating time

	Segment 1				**Segment 2**					
Product / Operation	**A**	**F**	**K**	**N**	**J**	**D**	**H**	**I**	**L**	**C**
AO1	0,7	1,2	1,2	0,7	1,2	0,4	0,8	0,9	0,8	0,0
AO2	1,5	2,1	2,1	2,0	1,0	1,4	2,2	1,3	2,2	1,7
AO4	2,0	2,5	2,5	2,0	1,7	2,2	1,5	1,5	1,5	1,0
AO6	5,7	6,8	7,3	5,7	3,1	3,7	3,1	4,2	2,5	2,5
AO7	0,0	0,3	0,2	0,2	1,1	0,2	0,3	0,0	0,3	0,3
AO9	1,4	1,5	1,5	1,1	1,4	1,1	1,7	1,6	1,6	1,6
A11	0,3	0,9	0,8	0,2	0,2	0,2	0,3	0,4	0,4	0,4
Sum	**11,6**	**15,3**	**15,6**	**11,9**	**9,6**	**9,2**	**9,1**	**9,9**	**9,3**	**7,5**

Figure 9. The same family of products but with numbers 1 and 2 placed instead of operating time

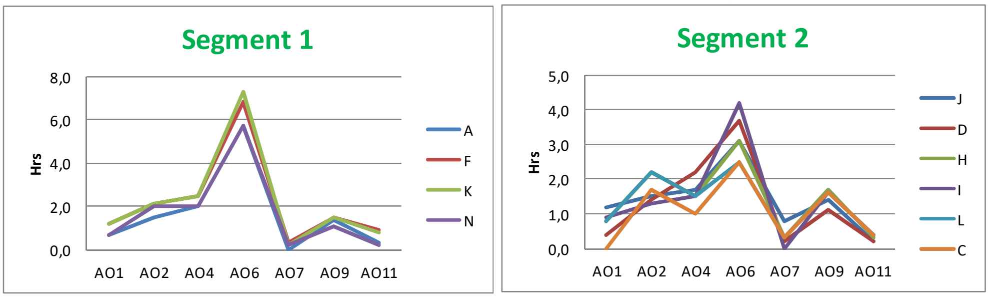

Figure 10. The same family of products after advance segmentation

6 CONCLUSIONS

In this case one segment of products is divided into two segments of about the same operating times.

This allows for company:

- provide starting of assembly at any time the material is available (simple planning rules - typical for order production) Improving the planning process = focusing on due date (typical for MTO and ETO environment),
- utilization of assembly lines without queues (all products in segment have almost the same operational time for assembly operations),
- reducing Work in Progress (acceleration of the flow without waiting),
- shortening of assembly time (lead time),
- increase labour efficiency.

An intelligent product is a physical and information-based representation of an item, which possesses a unique identification, is capable of communicating effectively with its environment, can retain or store data about itself, deploys a language to display its features, production requirements etc., is capable of participating in or making decisions relevant to its own destiny [McFarlane 2002]. Flexibility has become one of the most useful and necessary tool in today's competitive markets. Manufacturing flexibility is widely recognised as a critical component to achieving a competitive advantage in the marketplace [Jain 2013]. The global market are imposing strong changing conditions for companies running their businesses, something comprising complex and large scale systems [Leitao 2013]. Current requirements for continuous reduction of products, processes and systems life cycles increase the need of rapid design of lean and flexible production systems [Plinta 2016].

The main scientific contribution is the case study of the segmentation of product line in manufacturing enterpriseshowed an easier and more effective way based on the application of methodologies and product segmentation that can be applied choice of an optimal design solution of the dimensional structure (layout). ***The end result is that:***

- assembly line does not need to limited to realization of customer requirements,
- segmenting takes place at the beginning of the production process,
- planning is simple focuses on the arrival of the materials for the start of assembly and due date of the products.

The hypotheses introduced in introduction can be confirmed:
According to our method, if we try to segment products instead of components and assembly operations instead of machinerywe get a family of products that are similar and manufacturable at a specific assembly line without further additional complex calculations and determine the order of assembly.
In addition according their operational time the productivity of the line or direct labour increases due to eliminate WIP and production wastes such are waiting and non-balanced assembly operations.

Digitizing, modelling, simulation and emulation are used to understanding of comprehensive manufacturing processes and creation of new knowledge, which is used for optimization of real production systems [Gregor 2013]. Depending on the model, especially lightweight materials are used for the individual parts, for example, aluminum in the front end and chassis [Kohar 2014].

Intelligent manufacturing systems are socio-economic system with the ability to autonomously identify system changes and impulses from the environment, their causes and to use the obtained knowledge for self-learning, adapting and responding to all changes of the surrounding environment in a way similar to human response [Krajcovic 2013].The main task of manufacturing system reconfigurability lies in hardware and software components changing [Micieta 2015], [Rakyta 2014].

Reconfigurable manufacturing systems are proposed as a solution to unpredictable fluctuations in market demand and market turbulence [Westkamper 2009]. Realising cost-effective energy efficiency potentials will be beneficial not only for individual energy consumers but also for the economy as a whole [Micietova 2014], [Dulina 2014]. Many industrial companies still lack appropriate methods to effectively address energy efficiency in production management[Micieta 2016],

Reducing waste in manufacturingenterprises helps reduce manufacturing costs, and helps keep our industries competitive [Staszewska 2013].Advanced industrial engineering is focused on three mainsubgroups:industrial networks,adaptive production anddigital engineering [Micieta 2013], [Micieta 2014], [Binasova 2014]**.**

In the future, advanced segmentation can split products in an environment MTO to product families that have common features approximately the same operating times and thus increases the seriality of already existing assembly in middle and big sized companies without the voluminous of investment in the development and adaptation of products to the assembly process.

Area for further research may lead to high adaptability of assembly lines and design companies of future where customer requests are fulfilled fast and reliably by digital factory system with advance segmentation.

The main aim of this paper is the realization of the concept of education on the issues in MTO environment and order assembly production for products that takes assembly times by hours with high variability of options.

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