MAE-P^3 – A system to gain transparency of production structure as a basis for production relocation planning

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Abstract

The design of global production networks receives increasing attention, due to changing conditions in the international competition. The basis for relocation planning within a network is the transparency of the production structure.

The method MAE-P³ (MAE-P³: Machines And Equipment; Processes; Product flow; Planning) visualizes complex production structures in a two-dimensional matrix. It displays the sequence of the manufacturing processes of a production line and the sequence of the manufacturing processes of a product. The matrix allows comparing these sequences so that decisions about the relocation of a product within a production network can quickly be made and concepts for further production optimization can be deducted.

Based on this method, a computer aided system was developed to systematically compare the sequence of the manufacturing processes of a product to several production lines within the network. The comparison is predicated on an algorithm from the science of bio-informatics – originally developed for the comparison of protein chains.

1. Introduction

Due to changing international conditions – as for example the reduction of production lifecycle times, increasing globalization and raising competition –many companies pursue an internationalization of their production [1]. Two aspects are of major concern: Opening of new markets and reduction of production costs by relocating production from high-cost-locations (HCL) to low-cost-locations (LCL) [2].

Through internationalization, both reasons result in a network of production locations. The efficient design of global production networks has produced an increasing factor of success. Within the design of production networks, two types of strategies emerged:

One type may be titled "global strategy". This strategy focuses on world-wide homogeneous market segments and on an integration of the company's participation [3]. World-wide standardization of production and products and extensive centralization of the decision taking characterizes the approach. Locations of products, type of manufacturing processes, and manufacturer of resources are decided on centrally. This strategy provides cost advantages in the purchase of production resources and potentizes the knowledge about the application of manufacturing process and resources within the network.

Another type may be identified as "transnational strategy". This strategy concentrates strongly on regional expertise and on the resulting differentiated product- and production strategies [3]. Although a central decision procedure exists on products and locations, the choice of manufacturing processes and resource producers is in the discretionary decision competence of the local decision makers. This competitive situation between the decision makers produces plant-specific characteristics, especially with regard to the production structure.

Products may be of diverse complexity with the view to their manufacturability, e.g. at the ramp up of a new manufacturing process or when process is used, which is difficult to control. In these cases, only those products will be relocated to a LCL, which are expected to be produced reliably and cheaply. Mostly, products with a high degree of standardization and with a high rate of pay fulfill these requirements [4]. But also, a new LCL needs a certain size to operate economically and therefore products from different high-cost locations are being relocated to one LCL.

The new locations generate an additional complexity in the network. Therefore, production locations are divided into economic and technological hierarchic levels. It can be distinguished between lead centers and attached satellite plants. The lead centers are responsible for development, production and sales of certain products, while the satellite plants – or only satellite sections in a plant – work as internal suppliers [3]. Lead centers are usually based at a HCL where historically the expert knowledge is provided.

The lead center organization takes advantage of the transnational and global strategies. The lead center takes decisions on satellite sections concerning location of the product, resources, and manufacturing processes. The responsibility of the satellite plants rests in their own hands. In the context of this organizational concept, companies that followed originally a transnational strategy – strategy of competing plants – may counteract the complexity of production relocation.

If different products from different lead centers are accommodated at one LCL, an inhomogeneous production structure may arise at the new low-cost location. This is caused by the integration of production lines of independent and often competing lead centers. Differences in the lines may occur in type and sequence of resources, their components, their IT-infrastructure, or in the administration of production data. As a consequence, products from a different lead center cannot be transferred to another production line easily.

At the ramp up of a new plant, the inhomogeneity of the production structure does not cause many disadvantages because each production line is independently adjusted to its products and the forecasted volumes. However, a change in sales volumes may result in capacity overload or under-utilization of production lines. In case of capacity overload, production volume has to be transferred to a different line within the plant or a further production line needs to be ordered, which leads to increased fix costs.

The same problem occurs when further products or product volumes are relocated to the LCL. In this case, the required structure for products and free capacities must be identified. The more manufacturing processes a line has to deal with and the more production lines from various lead centers are relocated in the LCL, the more complex the relocation becomes from a technical point of view. The construction of new plants in the production network and the mixture of competing production units obstruct the overview of the network considerably. The fundamental problem is the lack of transparency in the world-wide production structure.

2. Objectives

The aim of this analysis is to generate a method, which visualizes the production structure of producing companies within a worldwide production network and allows comparing it. The idea is that decisions about the relocation of a product within a production network can quickly be made and concepts for further production optimization can be deducted.

One requirement for this procedure is to define the production structure by describing it comprehensively, but at the same time with a small amount of information volume. Therefore, the tasks are to identify the relevant describing parameters and to figure out where these relevant data can be collected within a company.

The next step is to develop a method to visualize the production structure based on the defined parameters and to configure the comparison of the production structure.

Based upon the visualization method, a computer aided system which systematically saves the collected production data and systematically compares different items of the production structure, is to be generated. The visual comparisons of different production lines and of product flows should be feasible and very flexible in order to allow very wide analyzing possibilities. Therefore the task consists in finding an algorithm that allows comparing visually different production lines with products, designated for relocation.

In this work, the system is used to identify production lines within a global production network – or within a plant – on which a certain product can be produced from a technical point of view. Besides the relocation planning of products, the transparency of the production structure also helps to find synergies in the inhomogeneous production structure of a new low cost location.

3. The method MAE-P^3 matrix and the computer aided system MAE-P^3

This chapter explains the method to visualize and compare a production structure – the MAE-P^3 matrix. Further, the computer aided system is introduced, which allows to generate the MAE-P3 matrix.

3.1. The method MAE-P^3 matrix

The first aim in this analysis is to describe the production structure comprehensively but also in compact form. The description of the production structure consisting of production lines and product flows requires relevant parameters:

1.) The first important parameters for the description of a production line and product flows are the manufacturing processes. On the one hand, manufacturing processes are accomplished on the resources of production lines. On the other hand, manufacturing processes are needed for the completion of products in the determined sequence.

In this context, the manufacturing processes are subdivided into three categories: value adding processes, non-value adding processes, and testing processes. Within the MAE-P^3 matrix, they are visualized by the symbols square, parallelogram, and rhombus (see Figure 1). The visualization of the matrix was inspired by the method of value stream mapping by Mike Rother [5].

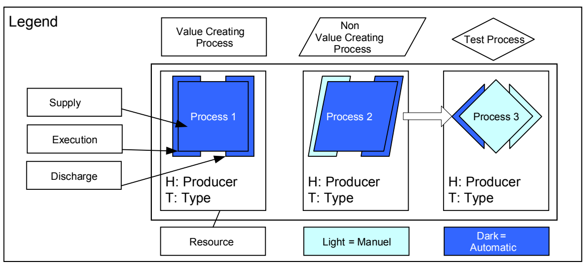

Figure1: Visualization of a production line.

2.) A next needed parameter is the degree of automation on a resource in a production line. Here, the degree is distinguished digitally between manual and automatic. The degree of automation describes the loading, the execution, and the unloading of the component. That shows how a component is transported to the manufacturing process, how the manufacturing process is executed, and how the component is transported away from the manufacturing process.

The MAE-P^3 matrix illustrates the degree of automation by colouring the manufacturing process symbols in a dark or light shade. The degree of automation for loading and unloading the components is indicated by dark or light patches next to the manufacturing process symbol.

3.) A further parameter is the resource with its manufacturer and its type. A rectangle surrounds the manufacturing process, indicating the resource. From the sequence of degree of automation concerning the loading and unloading of following manufacturing processes, the automatic chaining of the line can be identified. If a component is automatically unloaded from one manufacturing process and is also automatically loaded to the next one, then the two resources are chained automatically. The chaining of the resources is indicated by an arrow.

The three parameters manufacturing process, degree of automation, and resource constitute the minimum information necessary for describing one production step. Besides this minimum information, further parameters may be included, depending on the point of view or the industry sector.

Based on the defined parameters describing the production structure, the next task is to develop a production structure comparison method. The result is the method MAE-P³ matrix (MAE-P³: Machines And Equipment; Processes; Product flow; Planning).

The method MAE-P³ enables to compare several lines and product flows with a two-dimensional matrix. The abscissa shows the manufacturing processes, the ordinate represents the production lines and product flows. A production line indicates the physical sequence of the available manufacturing processes and a product flow shows the needed sequence of manufacturing processes to be manufactured.

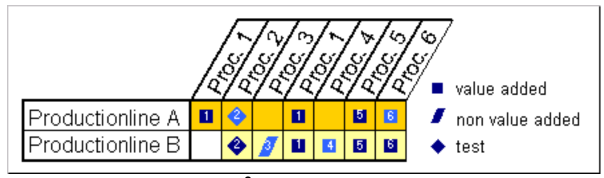

Figure 2. MAE-P^3 matrix with two production lines.

The method works as followed: Building up the MAE-P^3 matrix the first production line is inserted into the matrix. The name of the line is shown on the ordinate and all manufacturing processes are shown in the visualization with their value creation symbols. On the abscissa, the names of the manufacturing processes are written. The next step is to integrate the next production line under the already created production line.

However, only identical manufacturing processes may be inserted in the same column. If only one line possesses a certain manufacturing process, the other line needs a gap in this field of the column. Recursively, the earlier documented line may also receive additional gaps. Each integration of a further production line eventually causes more gaps to the new or already included lines. It is the aim to discover as many correlations as possible in order to find the common manufacturing processes graphically.

The product flows are displayed on the lower half of the ordinate. Each product flow is attached to a line. In order to represent a product flow, a production line is copied and integrated into the product flow (see Figure 3). Subsequently, it has to be examined whether the product needs all available manufacturing processes of the line for manufacturing.

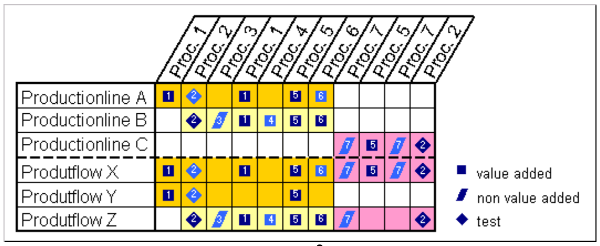

Figure3. MAE-P³ matrix in total.

In practice, one line produces several product families. Therefore, one line must offer all manufacturing processes that are required from the product families. As a result of this, resources of one line may not be demanded by some product families and act only in terms of transport functions. In such a case, this process is deleted from the product flow.

During manufacturing, a product often passes through several production lines. For this purpose, an additional production line is copied and added behind the production flow already created. Manufacturing processes that are not needed will be deleted.

Each production line receives a color symbol in the background and each product will be equipped with the same colour of the used line or lines.

3.2. The computer aided system MAE-P³

Based on the developed method MAE-P³, a computer aided system can be programmed. The aim of the system is to document systematically the required data of the production structure and to generate the MAE-P³ matrix automatically. Therefore, a comparison of sequences of manufacturing processes of lines and product flows must be enabled. Another requirement is to program the system flexibly, so that various analyses can be realized. Therefore the task is to find an algorithm that allows comparing visually different and changing production lines with products, designated for relocation.

The system MAE-P³ is based on a relational data base. For the programming, an open source language is used and the system is integrated into the intranet of a division of automotive supplier. The integration into the intranet supports promoting the system within the company, and in addition every location can use the same data base. An efficient way to record the required data of the production structure is collecting them down in the shop floor in front of the production line and using a predefined form. This procedure helps to describe the real production structure. In practice, the data of manufacturing process sequences and resources were searched within different departments within the company, but not every time the required data was documented or up-to-date.

To feed the data base, first the data of the production lines have to be inserted as described before. The next step is to include the product flows. Therefore, the list of a used production line is opened and stored under the name of the product. If certain manufacturing processes are not needed by the product, they are deleted them from the list. If a product needs additional lines, they will be attached in the same procedure to the created list of the product and unnecessary manufacturing processes are to be deleted as well.

Apart from the data administration, the MAE-P³ system should enable the visual comparison of product lines and product flows. If two production lines are chosen for comparison, the manufacturing processes of both lines have to be adjusted in a way that as many manufacturing processes as possible are displayed in the same column. For the adjustment, the system uses the option of inserting gaps between the manufacturing processes. For the dynamic calculation of where to insert these gaps between manufacturing processes, the MAE-P³ system employs an algorithm emanating from the bio-informatics.

Based on the discipline dynamic programming, Needleman and Wunsch published an article in the Journal Molecular Biology in 1970 [6]. The aim of their research was to develop a computer adaptable method for finding similarities in the amino sequences of two proteins. From these findings, it is possible to determine whether significant homology exists between the proteins.

The similarity of the sequences is measured by a number, which is called maximum match. One of its definitions is the largest number of amino acids of one protein that can be matched with those of a second protein allowing for all possible interruptions in either of the sequences. While the interruptions give rise to a very large variety of comparisons, the method efficiently excludes those comparisons from consideration that cannot contribute to the maximum match [6].

All possible pairs are represented by a two-dimensional array, and all possible comparisons are measured by a pathway through the array. For this maximum match, only certain of all possible pathways must be evaluated. A numerical value is assigned to every cell in the array representing amino acids. The maximum match is the largest number that results, when summing up the cell values of every pathway [6]. The developed algorithm is called Needleman-Wunsch algorithm.

The algorithm provides a comparison of proteins by adjusting the sequences of amino acids. The system MAE-P³ employs the algorithm in order to compare process chains. If two production lines are chosen for a comparison, the Needleman-Wunsch algorithm calculates the maximum match number that represents the highest amount of equal manufacturing processes in columns. The result is the MAE-P^3 matrix as a visual comparison of these two lines. The algorithm in the MAE-P^3 system is used to compare more than only two sequences of manufacturing processes.

Based on the dynamic calculation of the algorithm, one can choose production lines and product flows and then start the Needleman-Wunsch algorithm to create the MAE-P^3 matrix with its adjusted sequences of manufacturing processes.

The resulting visualization displays the production structure of a line, a plant, or a whole production network. This is the basis for relocation planning or for finding synergies in the production structure.

4. Relocation and optimization based on the MAE-P^3 system

The system MAE-P^3 provides different possibilities for finding synergies in the new LCL and for planning production relocation.

4.1. Planning of relocation

One aim of the MAE-P3 system is to compare any production line in the data base with another line or a product flow. With this functionality, a product designated for relocation will be compared by its product flow with the sequences of manufacturing processes with the product lines within the world-wide production network. One or several lines may be selected, which fulfill the requirements of the product flow. If the selection is done, the technical basis for relocation is given. If a product has already been designated for relocation for strategic or client-related reasons, a production line within this plant can be chosen by the help of generated MAE-P3 matrix.

The transparency of production structures is also of advantage within a plant at the LCL. If a production line is overloaded, the MAE-P^3 system can visualize all production lines of the plant and the designated product can be compared with the manufacturing process sequences of these lines. As a result, the decision on which line a product could be manufactured can be taken quickly. Other parameters may be integrated in the data base and examined as well, which might restrict the technical relocation. An example is a resource's rig size versus the dimension of a product. Another example could be the administration of production data that are required for the product by customers but cannot be offered by the resources.

4.2. Optimization of the production structure

Besides the planning of relocation, also structure optimization can be created, based on the transparency provided. Here, a project is introduced where the MAE-P^3 matrix was used for optimization of the production structure.

An automotive supplier runs a production department in a low-cost location. In one production department the range of products was constantly increased by product relocation activities while the production structure was not adequately adjusted. The consequence were 800 product variants, at least 95% of it were divided into 14 product families. The consequences for the production structure were various preliminary assembly lines, final assembly lines, single resources, as well as a very difficult to understand meshwork of product flows through the production structure.

The aim of the project was to readjust the resources to the necessary sequence of the manufacturing processes of the product flows.

The first step was to collect the data of the four pre-assembly lines, 10 final assembly lines and single resources as well as of the 14 product family flows and provide the MAE-P3 matrix. Then the MAE-P^3 matrix was printed as a poster, put on a wall and used in a workshop to analyze the production structure.

First, cluster of similar sequences of manufacturing processes of products were build by investigating all 14 product flows. The determination showed which products have the same request of sequences of manufacturing processes. Thereupon, the required capacity per cluster was established. By examining the cycle time per process step, determination of the bottleneck, and consideration of the planned quantities, the required number of re-sources for fulfilling the demand of a product cluster may be discussed. Based on the quantified demand clusters, production lines could be developed, by reorganizing the resources of the former structure to the new developed structure.

The result is a production area with defined preliminary assembly lines, defined intermediate storages (supermarkets) and product family specific final assembly cells. The workload of the resources could be raised, the quality improved, and the number of employees could be reduced.

5. Conclusion

Based on identified parameters describing the production structure of a global production network, the method MAE-P^3 matrix was developed. The method MAE-P³ (MAE-P³: Machines And Equipment; Processes; Product flow; Planning) visualizes complex production structures in a two-dimensional matrix. It displays the sequence of the manufacturing processes of a production line and the sequence of the manufacturing processes of a product.

Based on this method, a computer aided system was developed to systematically compare the sequence of the manufacturing processes of a product to several production lines within the production network. The comparison is predicated on an algorithm from the science of bio-informatics – originally developed for the comparison of protein chains.

The MAE-P³ matrix shows the similarities between production lines and a certain product, which is intended to be relocated. By comparing the sequences of manufacturing processes of the chosen production lines to the manufacturing processes required for the product, the procedure supports the decision-making of the relocation from a technical point of view, making all relevant technical information centrally available.

Also, the MAE-P³ matrix can be used to in a first step visualize and then to optimize inhomogeneous production structures of newly built low cost location plants.

Many parameters affect the decision of a production relocation. Culture, degree of education, labor costs or political stability are just a cutout of the variety of parameters affecting such a decision. The method and the system MAE-P³ is a contribution to the technical aspects of a relocation decision.

6. References

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