Globally Distributed Manufacturing Networks: Interdependencies between Product Design and Choice of Production Site

Matthias Grauer, *Robert Bosch GmbH, Stuttgart*

***Abstract*— Manufacturers are subject to an enormous cost pressure. Opportunities owed to globalization, such as advantages of one production site over another, have to be put in good use. Therefore, a production segmentation followed by a production allocation has to be realized for the best assessed manufacturing sites. The allocation is possible only in case of products, that lend themselves for modularization and in case of manufacturing sites, that can meet the requirements specific to the product modules. The present article introduces a method for assessing the interdependencies between product design and choice of manufacturing site. The article also provides an eligible approach to a solution.**

***Index Terms*— know-how protection, manufacturing network, manufacturing site assessment, product segmentation.**

I. Strategy and Implementation

The Robert Bosch GmbH, in the words of CEO Franz Fehrenbach, uses the following strategy to face the challenges of globalisation: "The combination of know-how at traditional Bosch sites and production in low-cost countries ensures our competitive strength worldwide [1]." Hence local differences have to be deployed to tackle global risks. What is more, differences in the levels of development and qualifications are the cause for companies to spread and segment production globally. This segmentation requires modularisation of both products and production sites that match the individual requirements of each module. Any method supporting the implementation is further complicated by the complex interdependencies of product design, process design and location selection as described in [2]. This article presents a solution approach to handle the interdependencies of product design and location selection as part of the holistic production strategy described in [2]. The implementation has to be pursued on strategic as well as on operative company levels. These levels are depicted in figure 1 by two horizontal layers and two vertical views.

Manuscript received May 15, 2007. This work was developed by the Corporate Sector Research and Advance Engineering of the Robert Bosch GmbH in Stuttgart, Germany. The exact designation of the division is Applied Research 2, section Integrated Component Design.

Matthias Grauer is with the Robert Bosch GmbH, PO Box 106050, Stuttgart, 70049, Germany (phone: +0049 711 811-48764; fax: +0049 711 811-5180707; e-mail: Matthias.grauer@de.bosch.com).

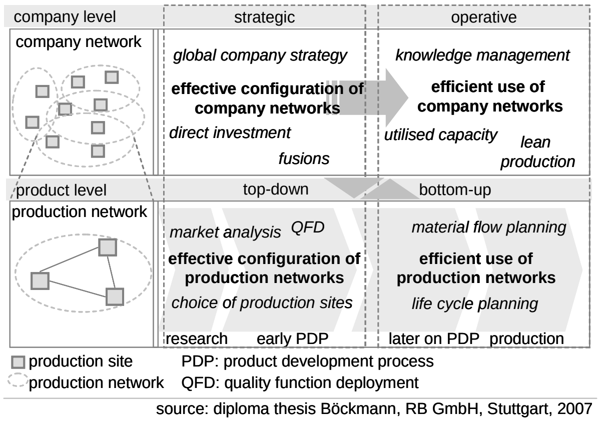

Figure 1: Interrelations of strategic and operative levels [8]

The strategic view aims at the effective configuration of the production network. The operative view targets an efficient company under varying global conditions. As the strategic view is always the basis for operative decisions, the success of the overall company layer depends on the success of the product layer. Therefore the early stages of product development form the largest leverage for optimisation and success (lower left corner, fig. 1).

II. Location Assessment

The configuration of an effective production network is rendered difficult by the lack of modular products to distribute in the network or because of production sites that do not meet the requirements of modular products.

To be able to turn local differences between the production sites into advantages of a production network it is necessary to assess local conditions based on the requirements. The requirements at the product level are defined by product and process design [3]. Only in few cases it will be possible to find the optimal site meeting all the different requirements. If a product for example contains labour-intensive and know-how bearing components, moving its production to a low cost country (LCC) is one option. In this case choosing the LCC means to neglect additional costs for the development of local experience and for the protection of product know-how. A solution would be to separate the labour intensive parts from the ones that bear the company's know-how. After defining interfaces the optimal site for each component (module) can be

ISBN:978-988-98671-6-4

identified. Hence the optimal modularisation and allocation of modules to production sites is the aim of the method presented here.

III. PRODUCT DESIGN AND LOCATION SELECTION

Design decisions predominantly define the requirements of the product towards the production site. They comprise qualitative requirements, requirements of the selected manufacturing process and quantitative process requirements such as lead-time or labour time [4]. The design engineer needs to know about the effects of design decisions in order to choose the optimal modularisation for the product.

Product development needs a tool that assesses product requirements, compares them to site conditions and returns estimated costs as well as measures for improving the design.

IV. METHODOLOGICAL PROCEDURE

The method introduced in this article represents a part of the overall production strategy of [2] and aims at two major targets. The first one is to return the costs that design decisions result in. The second one is to generate design measures that lead to a design in compliance with local site competencies.

Figure 2 shows an overview of the method. The product design process which leads to technical solutions and a product structure is supported by tools. They focus on the development of a modular product structure which is a prerequisite for globally distributed production networks. The modules can be developed and manufactured independently.

Thus the modularised product concept constitutes the input for the method. The single modules are assessed with qualitative criteria and allocated to a range of appropriate production sites. This preliminary selection afterwards has to be optimised by including quantitative criteria. The resulting overall assessment of scenarios is then being used to deduce further optimisation measures.

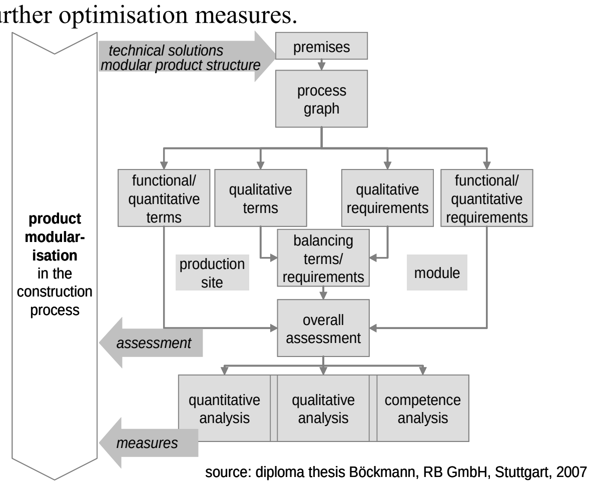

Figure 2: Structural layout of the method [8]

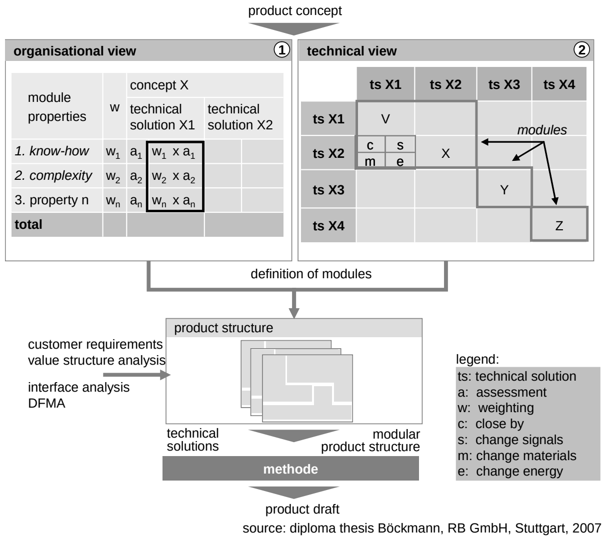

Figure 3: From concept to draft [8]

V. MODULARISATION

Established tools have been customized and integrated to represent internal and external customer demands in product properties, product functions and technical solutions [5]. Figure 3 shows the most important step, even the development from concept to draft stage.

Similar to the module drivers of Erixon [6] the modularisation starts with the “organisational view”. Therefore the technical solutions that form a concept are entered in a matrix with module property categories. These weighted (w) assessment categories are stability, capability, know-how, complexity and flexibility. A know-how property of a technical solution that is rated high suggests designing this solution as a separable module to ensure the protection of knowledge.

After the “organisational view” there comes the assessment from a “technical” viewpoint. The interactions of the technical solutions are taken into account by conducting physical interdependency and effect analysis. The “technical view” helps validate the defined modularisation from an organisational point of view [7]. It results in alternative product drafts that contain differing proposals for modular product structures. The next step is to evaluate these drafts in order to achieve a continuously diminishing solution space.

VI. EVALUATION OF PRODUCT DRAFTS

Next the single modules that form a product have to be assessed using qualitative criteria. The evaluation is done according to assessment schemes for each of the criteria mentioned in the chapter “modularisation”. The schemes contain rules with indicators and keys to be used to gain an objective overall rating. For every criterion a second scheme has been developed to evaluate the site conditions. This scheme can be used for already existing production sites as well as for potential new ones. The site evaluation is done locally, stored in databases and continuously updated. When looking at a new product draft only the product itself has to be evaluated. The database provides the information about the site conditions.

The next step is to compare the module's requirements with the site conditions. This leads to a key figure that states the solidity of requirements and conditions. With this figure it is possible to set up a ranking of production sites for each module. The engineering team manually selects sites that require further analysis. Furthermore strategically defined production sites and production volumes are important to the selection process. This step helps reduce the solution space and leads to a shorter lead time for optimisation algorithms in the overall evaluation.

Assessing the individual design features of each module is the next step. If necessary the module's design features have to be divided into subgroups. In a single module one subgroup for example is made out of the features "shape tolerance" and "height" and another one out of "blind hole" and "location tolerance". Each subgroup is assigned one or more alternative production processes. Combining a design feature with a production process, results in a figure representing the degree of difficulty and in process attributes such as lead time or labour input. The degree of difficulty states to what extent a production site has to be proficient in the specific production process. The process attributes form an important part of the following overall evaluation.

The foregoing assessments are to be integrated into a mathematical model. An algorithm with quantitative target values leads to assessed module-location-scenarios of production networks. Other inputs are company targets (e.g. high capacity utilisation) and product targets (e.g. minimal cost of production, logistics, lead time). For every scenario there are three key figures (fig. 4):

Quantitative
>Represents a relative assessment of the total landed costs.

Qualitative

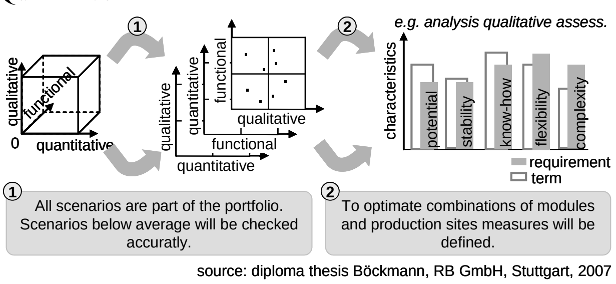

Figure 4: 3-dimensional analysis of module assessment [8]

>Represents the solidity of module requirements and site conditions.

Technical
>Represents the solidity of technical requirements determined by the production process(es).

Explicitly these figures are not offset against each other. Instead, they are used in an in-depth analysis.

VII. Analysis

The quantitative target values in the optimisation algorithm may lead to suboptimal allocation of modules to production sites. Furthermore strategic prerequisites such as the given site network, customer demands or political events may cause the current product design to be inadequate for making use of local advantages. Accordingly low rated scenarios have to be further analysed so that measures can be determined that help amend the product/module design:

The target of quantitative analysis is to identify modules that have not been designed according to local factor costs like cost of labour or capital. The general rule is that the utilisation of a factor (e.g. long labour time) has to match its costs (e.g. low labour costs). This analysis determines the overall orientation of design amendments in the module/product.

The qualitative analysis reveals shortcomings in meeting the module's qualitative requirements at a production site. The aim is to reduce the requirements. High know-how safety requirements for core competencies for example can be significantly lowered by introducing technical safety measures like copy protection. Always another option is to separate the parts that cause high requirements for a module. This leads to a review of the modularisation.

The technical analysis may result in determined cost to build up required technical qualifications at a production site. By analysing the similarity of current processes to new ones the investments for machinery and equipment can be adjusted.

Each in-depth analysis tries to harmonise the production processes used at a specific production site. Modules with similar requirements form groups that may be interpreted as 'production modules'.

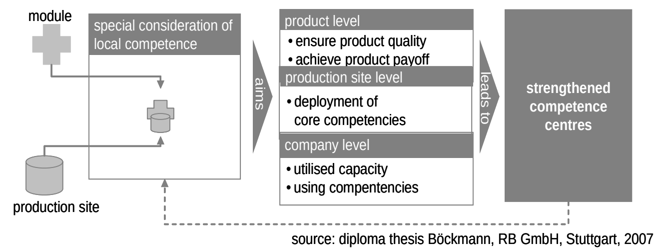

Figure 5: Effect of the method for applying companies [8]

VIII. Editorial Policy

To successfully implement the method it is essential to generate early wins and to initiate long term changes in time. In a mid to long term it is necessary to focus application of the method results in strengthened competence centres. Every production site will be able to use free resources to further develop its core competencies as shown in figure 5.

IX. SUMMARY

The method creates a heightened transparency for the effects of design decisions. If the method is successively used with alternative product drafts, the key figures are used to compare the total landed costs of one design. For each individual draft the method reveals a suboptimal design. It also generates the corresponding measures to advance the design towards a design according to local competencies.

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