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Design of a Scalable Modular Production System for a Two-stage Food Service Franchise System

Regular Paper

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Abstract The geographically distributed production of fresh food poses unique challenges to the production system design because of their stringent industry and logistics requirements. The purpose of this research is to examine the case of a European fresh food manufacturer's approach to introduce a scalable modular production concept for an international two-stage gastronomy franchise system in order to identify best practice guidelines and to derive a framework for the design of distributed production systems that perform in a highly dynamic environment. The design framework was developed by creating a theoretical model through literature review and the thorough analysis of an industrial case. Information was collected through multiple site visits, workshops and semi-structured interviews with the company's key staff of the project, as well as examination of relevant company documentations. By means of a scenario for the Central European market, the model was reviewed in terms of its development potential and finally approved for implementation. However, research through case survey requires further empirical investigation to fully establish this approach as a valid and reliable design tool.

Keywords design of production systems, empirical study, modular concept, franchise model

1. Introduction

Increasing market dynamics require manufacturing companies to become even more flexible: nearly unpredictable sales volumes and shorter innovation cycles require production systems that not only produce high-quality products at low cost, but also allow for rapid response to market changes and consumer needs. Responsiveness can be defined as the speed at which a production system can meet changing market and business targets in terms of volumes and product mix, and launch new products, product changes or variants (Koren and Shpitalni, 2010). However, an increase in responsiveness usually impacts resource utilization causing important cost disadvantages (Reichwald et al., 2005). This particularly applies to those industrial sectors that are traditionally driven by mass-production and thus have a high level of automation like food industry. Moreover, markets and competitors in recent years have become increasingly global. Especially for medium-sized producers of fresh foods or foods with short shelf life, this becomes a growing logistical challenge, especially due to quality aspects (Van Der Vorst, 2009). In this context, production system design becomes an increasingly complex and dynamic task, focusing not only on the efficient and systematic organization of the production resources within a single production system but also extending the boundary of design to a corporate value chain of various individual production systems interacting in collaborative production networks (Shin et al., 2009). Consequently, a methodological approach for the design of networked production systems is required that is not only flexible and responsive regarding volume or variant variations but also capable of controlling its complexity.

Production systems are collections of diverse production resources like human resources, machines, equipment and procedures organized to accomplish manufacturing and/or assembly operations with the final objective to add value to a part or product (Groover, 2008). In this paper, this definition is extended by a network component. Accordingly, a production system is defined as a scalable collaboration network of distributed modular production resources, and its structure evolves in accordance with market and environmental dynamics.

To meet the requirements of a continuous and autonomously regulated adaptation of structures, processes and organization to a quickly changing environment, different philosophies of distributed manufacturing such as a bionic or biological manufacturing system (Okino, 1993; Ueda et al., 2001), a holonic manufacturing system (Mathews, 1995; Van Brussel et al., 1998; Zhang et. al., 2000; Babiceanu and Chen, 2006; Lee and Banerjee, 2011), a fractal manufacturing system (Warnecke, 1993; Ryu et al., 2003; Ryu, 2003; Ryu et al., 2006), and an autonomous manufacturing system (Park and Tran, 2011) have been proposed. All of the concepts have basic properties in common, including autonomy, distribution, decentralization, and flexibility, adaptability, and agility (Ryu, 2003). They are conceptualized to continuously adapt their organizational structures to changing environments by means of self-organizing mechanisms, considering that a production system is an organic complex consisting of diverse autonomous units, i.e., a fractal, a cell or a holon (Shin, 2009). Diverse authors also provide a comprehensive comparison between distributed manufacturing approaches such as bionic, fractal and holonic manufacturing systems, in terms of design, features and performance (Tharumarajah et al., 1996; Sitorus et al., 2006) and use them also in the context of network approaches (Montreuil et al., 2000; Frayret et al., 2001; Hongzhao et al., 2005). Some other research has extended the focus from level of the organizational structure towards a more comprehensive understanding of a production system's dynamics: diverse authors promote the concept of agility (Yusuf *et al.*, 1999; Dove, 2006; Matt, 2010; Vinodh, 2011), changeability (Wiendahl and Heger, 2003, Wiendahl *et al.*, 2007; Park and Choi, 2008; AlGeddawy and ElMaraghy, 2009) or mutability (Spath and Scholz, 2007), mostly referring to the same or at least a very similar idea of a manufacturing system that shifts quickly between product models ideally in fast response to customer demand (Matt, 2010). Finally, some recent research has investigated aspects of cross-enterprise production and supply chain design focusing, however, mainly on aspects of process module based modeling of process chains (Aurich *et al.*, 2008) or collaboration based aspects with a special focus given to social and interpersonal factors (Jaehne *et al.*, 2009).

Although much research has been carried out in order to establish dynamic and self-organizing systems by means of fractal, bionic, holonic, autonomous or agile approaches, the main focus has been given always to isolated aspects of layouts, organizational structure, process design or collaboration mechanisms. A comprehensive approach for the design of scalable modular production systems that promote distributed production in collaborative networks in a highly dynamic environment is still missing.

Thus, the research presented in this paper aims at developing a methodological framework for the comprehensive design of a scalable and modular collaborative production network that enables a quick and self-evolutionary adaptation to changing market and environmental conditions. For this purpose, a conceptual framework is derived from the detailed analysis of an industrial case dealing with the design of a scalable modular production network for an international two-stage franchise system in the field of exquisite fresh food.

The paper is organized as follows. Section 2 is devoted to the description of the objectives and methodology of the case study based research. In Section 3, the industry case study is introduced in detail. Section 4 illustrates and discusses the results of the case analysis. Finally, Section 5 discusses the implications of the research findings and further research work.

2. Research methodology

"To achieve relevance, we must embed ourselves, from time to time, in field-based research" (Fawcett and Waller, 2011, p. 4). Case research is one of the most powerful research methods for the development of a new theory in the field of industrial engineering, particularly in today's turbulent environment (Voss *et al.*, 2002; Perren and Ram, 2004; Zalan and Lewis, 2004). Case research uses case studies at its basis to study different issues within the same subject of investigation or to research the same issue within a variety of different contexts. Case studies do not necessarily have to be based on existing literature or on empirical evidence. So the case study research can be used to build a new theory (Eisenhardt and Graebner, 2007), even though so far little is known about the investigated phenomenon (Vissak, 2010). Case research has been recognized as being particularly suitable to ask "what" and "how", but also "why" questions, usually when doing research in a very dynamic, experiential and complex context (Yin, 1994). Thus, case research is appropriate especially for theory building, testing, refutation, refining, hypothesis development and prediction (Woodside and Wilson, 2003; Gummesson, 2005; Vissak, 2010) as well as for the identification of further research needs (Halinen and Törnroos, 2005; Siggelkow, 2007).

Despite its usefulness, there are several challenges in case research: it is usually time-consuming and labor-intensive, and it needs experienced and skilled interviewers to get the right information and to carefully draw conclusions from it in order to ensure rigorous research. Under these conditions, case research leads to new and creative insights and theories that have not only a strong impact on the scientific community but also have a high validity with practitioners – many of today's important concepts and theories, like for example lean manufacturing, have been developed on the basis of case research (Voss, 2002).

Case research typically starts on the basis of a conceptual research framework and the derivation of suitable research questions.

The conceptual framework of the research reported in this paper starts from the identification of the need for the development of a comprehensive approach for the design of scalable modular production systems that promote distributed production in collaborative networks in a highly dynamic environment. The following research questions are derived:

- How is an ideal, geographically distributed and collaborative production system designed?
- How can the system design fulfil the requirement of a high and stable operational performance in terms of quality, cost and service level and allow a maximum adaptation to the externally induced volume and variant changes at the same time?

It is common in case research and strength of the method that the initially defined research questions evolve over time as more and more knowledge about the subject is developed. Thus, at this stage the research questions are tentative and have to be refined ideally at the very beginning of the case study research in order not to risk degenerating into a "fishing expedition" in which the formulation of the research question is driven by the principle of hope (Voss *et al.*, 2002). The refined questions of this research will be presented in Section 3 after a general introduction into the industrial case.

During the case research, three main sources were used for information and data collection: (1) workshops with company staff, (2) semi-structured interviews with staff at the company, and (3) collection of documents and historical data from electronic databases/spreadsheets and documents such as sales forecasts, production schedules, technical data and record sheets of production machines and equipment, supplier quotations for machines and technical equipment, expected deliveries and actual deliveries records, and related developments of product variety.

3. Case study

The empirical basis of this paper is a single case study involving two production sites of a European medium-sized producer of fresh food, hereinafter referred to as "the company". Several years ago the management decided to explore a new business opportunity in the field of food service franchising. A project was launched with the aim of building a franchise concept for upscale system gastronomy. Apart from product and market related issues, the franchise-model should also provide a solution for a scalable logistics and production concept.

In order to refine the general research questions outlined in the previous section, an initial workshop involving technical and management personnel from different functional areas of the company was organized by the research team. In this workshop, the research framework was developed and visualized in a graphical form in order to study the key factors, constructs, variables and the presumed relationships amongst them (Voss *et al.*, 2002).

The conceptual framework shown in Figure 1 helped the team to select the constructs and variables that should be included in the study and to refine the research questions. The general concept provides a two-stage franchising system, often referred to as "master franchising". This system allows a so called master franchisee to purchase the rights to sub-franchise within a certain territory and to grow a profitable business in a fairly short timeframe. On the basis of this general concept, the company founded the franchisor as a spin-off and a legally independent unit. The franchisor assigns a defined market territory to the master franchisee who then recruits franchisees to open units within this area. The master franchisee pays a portion of the royalties generated from its territory to the franchisor and receives in return support and expertise as well as access to new products, systems and technologies.

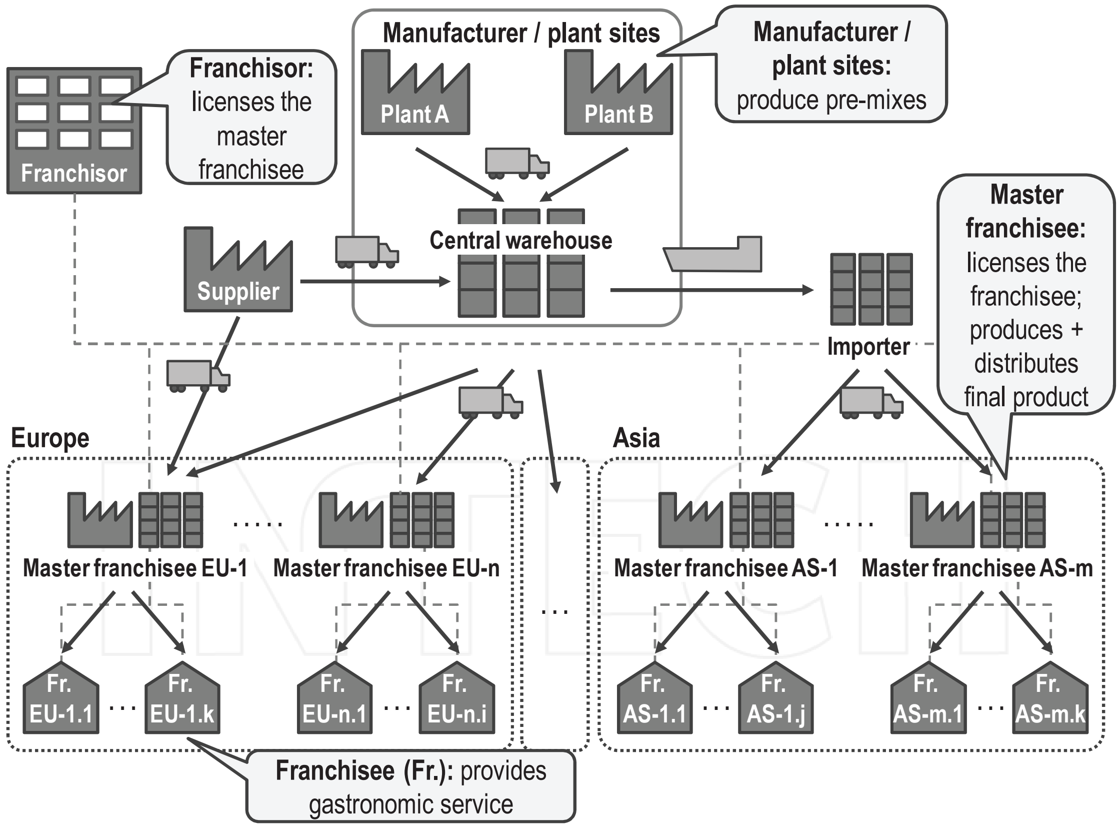

Figure 1. A conceptual production network design as a starting point for the refinement of the research questions.

One of the biggest challenges in the system gastronomy franchising, however, is the design of an efficient and reliable production and distribution network. Figure 1 shows the main principles of the conceptual framework: the company with its two manufacturing plants produces centrally highly standardized components, called "pre-mixes", according to a strictly secret recipe and delivers these pre-mixes to a central European warehouse. The pre-packaged mixes are very compact, have high value to weight ratio and can be stored for relatively long, so that a central storage with worldwide distribution is the most efficient logistical option. Other components that are delivered by suppliers may be passed by the central warehouse or be directly shipped to the next destinations. Within Europe, these next destinations are the single manufacturing units located at the master franchisee whereas for example for Asia, the distribution to the master franchisees is managed by a general importer. The manufacturing of the final products is performed by the master franchisee who delivers them to the franchisees' outlet stores within his territory; bilateral delivery agreements between master franchisees in different areas are allowed if this option is more cost efficient than the expansion of the own manufacturing capacities. This production system has diverse challenges in terms of quality, cost and service level, but especially regarding the fast and cost efficient adaptation of manufacturing capacity to market requirements. Accordingly, the following refined research questions can be derived:

- What are the basic system components in the networked production system? What component variations have to be considered in order to allow a fast adaptation to changing volume requirements?
- How can these system components be standardized in order to set the same manufacturing standards on an international level in terms of quality, cost and service level?
- What mechanisms for the timely re-design of the production network have to be introduced in order to meet or even anticipate changing market or environmental conditions? How are these mechanisms triggered?

The answers to the above questions will be elaborated in the next section, which presents the findings produced by the case research in interplay between practical report and theory building.

4. Findings

As already discussed in Section 2, theory building can be considered a major strength of case study based research. In the following, the theoretical framework for the design of a scalable modular production network is systematically derived from the analysis of the industrial case of a two-stage food service franchise system outlined in Section 3.

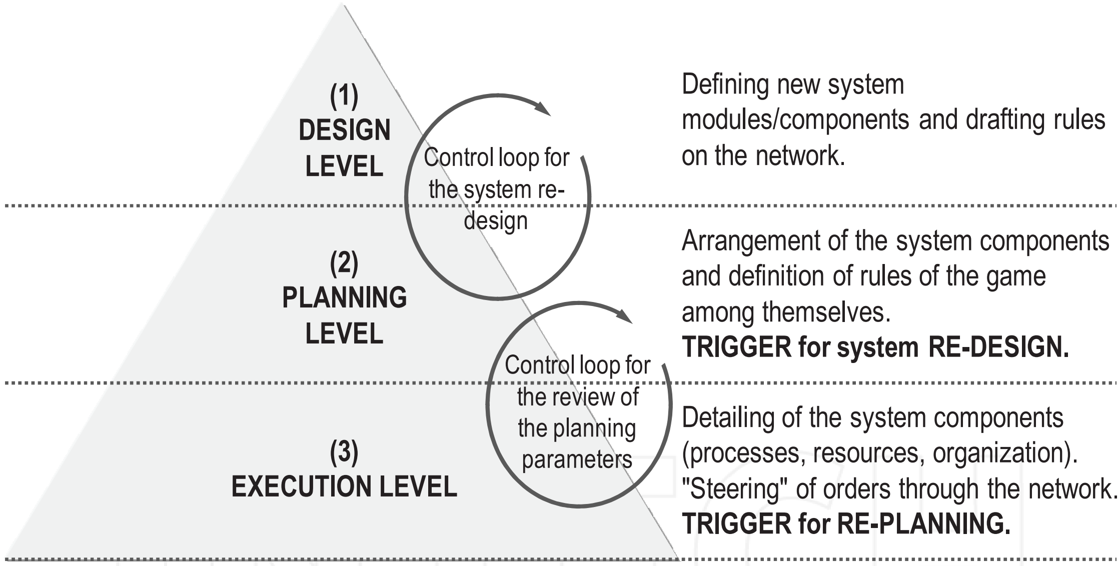

Figure 2. The design framework consists of three levels.

4.1 Design framework and basic definitions

In order to have an ordering scheme and a common language that guide through the complexity of the overall project, the company project team developed a set of basic definitions and a design framework consisting of three levels:

(1) At the design level, the production system and its subsystems called production modules or system components are defined and the rules of the networked production system design (e.g. basic production modules, scalability, range of operational flexibility, interfaces and interactions) are established. This level is strategy-oriented and has a long-term time horizon of 3-4 years.

(2) The planning level includes the planning process, which deals with the assembly of the production modules into an interactive network according to the established rules. It translates actual requirements regarding product mix and volumes from the outlet store network into operative production and delivery plans. The time horizon on this more tactical oriented planning level is aligned with the medium term (3-6 months)

(3) On the execution level, all operational processes are defined in detail. Since decisions on this level are often made at very short notice, great emphasis is placed on standardized processes which promote fast and failure-free operations.

In accordance with the previously defined research questions, the focus of the case research was put on the development of a deeper understanding of the mechanisms on the design level.

However, as Figure 2 shows, there is a significant interaction between the three levels consisting in control loops. The aim of the integrated production network design on the design level is a future-oriented set-up of a network model that can meet the product requirements in a specific region considering local circumstances, and the strategic definition of master franchise locations. To capture all these requirements, four basic design fields were identified on the design level:

- product range strategy (complete assortment, mandatory product range for all outlet stores, optional standard range, make or buy rules)
- production system design (definition of basic manufacturing unit, scalability model, capacity per level in # outlet stores, investment per level)
- logistics (central storage requirements, ordering procedures, guidelines for supply, delivery range) – this aspect is not reported in this paper.
- franchise model (definition of processes, procedures and responsibilities, franchise manual) – this aspect is not reported in this paper.

The following sections are devoted to the first two of the above design fields.

4.2 Product range strategy

The starting point of the networked production system design is the definition of the general product range strategy, including, however, a more detailed analysis of the structure and the market potential of a local region but also the product range that will be offered in this specific region. In the present industrial case, the product range strategy had been defined and agreed beforehand, considering the following aspects: definition of the complete available franchise assortment, mandatory product range for all outlet stores (worldwide), optional standard range (regional), make or buy rules. Thus, it can be considered a necessary given input to the system design which won't be subject to further detailing within this case research.

4.3 Design of scalable production modules

In contrast to the planning level, which aims at performing a continuous optimization of the designed networked production system on the basis of specific requirements within defined corridors of volume and variant flexibility, the design level is primarily needed for studying and modelling the future production system and network structure (units, capacities, locations, relations). This is based on long-term forecasting and strategic objectives. The common goal of the work performed on the design and planning level is the provision of a networked production system that operates in the total cost optimum. Consequently, two conditions must be met: First there is the necessary condition of optimal site selection. This is typically a logistical network planning issue, mainly conditioned by times and costs of transport from the production location (master franchisee) to the single outlet stores (franchisees) as well as by costs and availability of suitable facilities and personnel. All these factors vary greatly depending on the selected region; their scientific exploration deserves separate consideration and is excluded from the present work. Second, there is the sufficient condition for cost minimization, i.e. the determination of the most cost-effective and at the same time highly adaptable production system design. To meet these requirements, it is necessary to consider design elements such as process optimization and standardization in the phase of system design. This can be best achieved by defining a set of modular and scalable system components (production modules). Against this background, a production system is incurring from the assembly of production modules selected and dimensioned according to a defined set of criteria and rules which will now be discussed in more detail.

On the basis of a careful review of existing literature, with a special focus given to holonic and fractal manufacturing systems, and the practical insights taken from a former analysis of best practice industrial solutions in production system planning (Matt, 2005), the following principles for the design of the modular and scalable production modules were applied by the project team:

- Clear assignment of product families to a production module
- Strict orientation to flow principle to promote maximum efficiency
- Volume flexibility (within predefined limits and rules)
- Complexity reduction by separation of very complex or individual production processes from standard processes
- Standardisation of proven concepts

In a first step, product families were identified using the rank order clustering technique (King, 1980). This algorithm helps to efficiently solve the product and machine/process grouping problem by reducing the part-process matrix to a set of diagonalized blocks that represent product families and their associated process or machine groups (Groover, 2008) that will be assigned to a production module. In total 26 basic products plus variants were grouped in 4 product families. Following the design principle "complexity reduction by separation of very complex or individual production processes from standard processes", one product family was kept separately as it depends on very region-specific parameters and thus cannot be subject to standardisation. Moreover, it contains still many uncertainties and has to be re-discussed on a strategic level. The three remaining standard-product families will from now on be identified by the letters "A", "B" and "C".

In a next step, the manufacturing processes of the single production modules were designed. So far, the company had made only first manufacturing experiences in laboratory setting in a very manual and experimental environment. This had been sufficient, since the quantity requirements of the first tentatively opened outlet stores were still manageable. However, the market success and the next sales forecasts suggested to quickly ramp-up the new production system. Thus, suitable machines and manufacturing equipment had to be selected and assigned to the product family related processes.

To achieve a scalable production system, for every production module an expansion-stage model was developed, Figure 3 shows the example of product family A. This procedure was also repeated for the other product families to get a tool kit for quick and easy composition of the production system. Using this modular system, in principle an individual production concept can now be configured for each master franchise area according to the region-specific requirements regarding volumes and product-mix (of standard products). In a next step, the Central European market was selected as a case study region to verify the model using market scenarios.

4.4 Scenario based review of the proposed model

To facilitate comparability between different product families a common reference for the scaling was determined. In collaboration with the sales and marketing department therefore a so-called standard outlet store for the Central European market was defined on the basis of a careful analysis of the data and experiences of the existing five outlet stores, assuming a standard sales volume and a constant product mix. Of course, this assumption has to be reviewed on a regular base and is therefore subject to the control loop between level 2 and level 1 in the design framework shown in Figure 2.

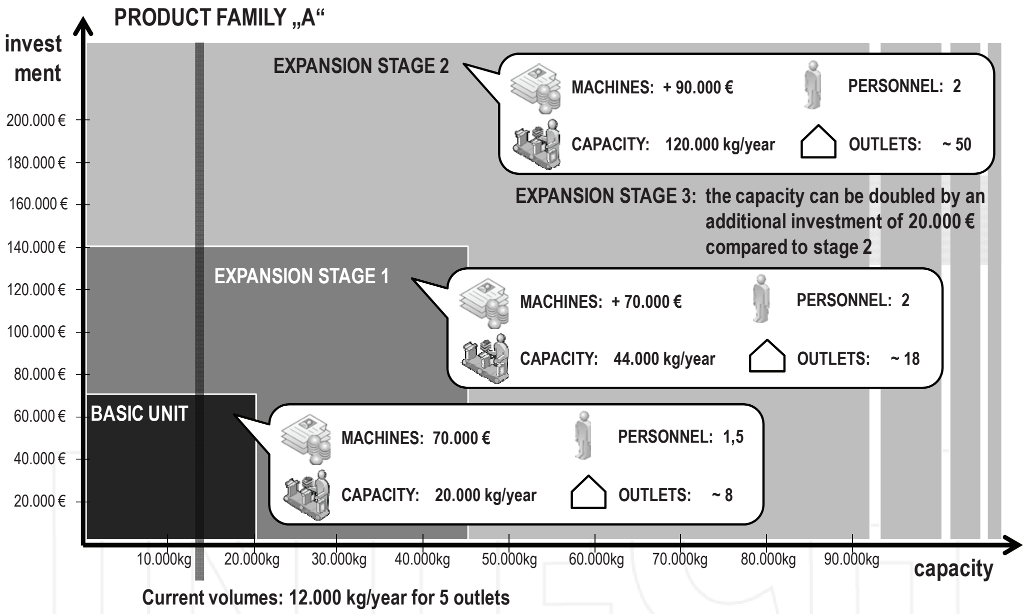

Figure 3. Expansion-stage model for a scalable production module using the example of the product family "A".

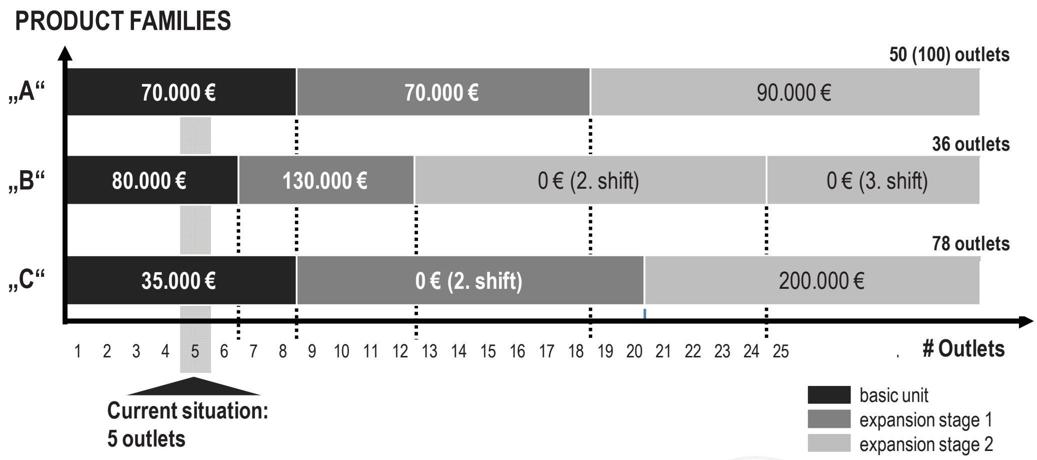

Figure 4. Overview of the expansion stage model.

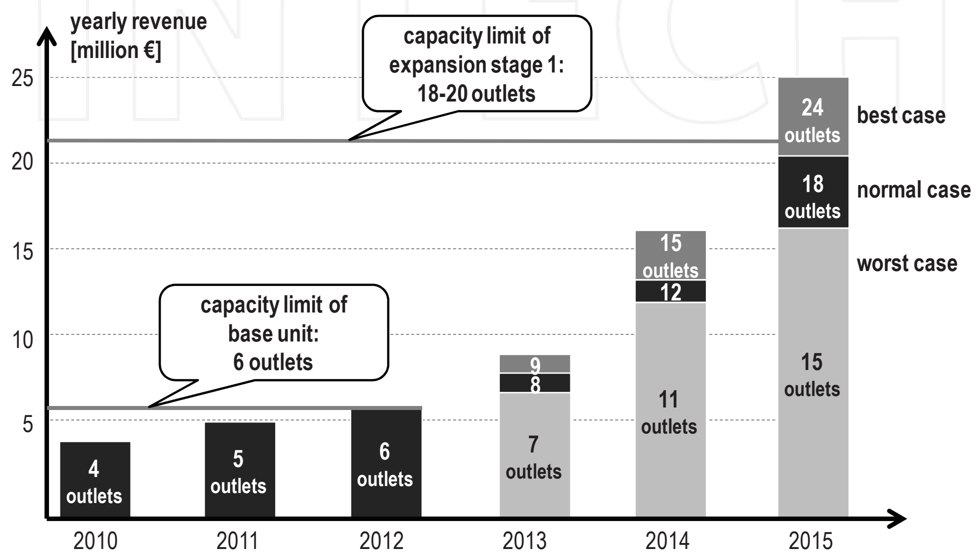

Figure 5. Illustrative verification of the model using a 2015 scenario for the Central European market.

With the definition of the standard outlet store, the scalability of the production system can be measured even more easily. This is needed for the future-oriented design of the distribution network. The direct comparison of the three product families' development models shown in Figure 4 illustrates the expansion steps:

- The production module base unit can supply up to 6 outlets.
- With the first expansion stage, 18-20 outlets can be supplied (2nd shift for B).
- The second stage highlights again the bottleneck: the production module for product family B can serve a maximum of 36 outlet stores in stage 2.

For the fulfillment of the current business plan with a planning horizon to 2015, these options were considered sufficient for a gradual expansion (Figure 5).

Finally, a standard investment calculation for the production modules and the single expansion stages was performed considering only those cost factors that are independent from regional specifics, such as investments in machines, equipment and other technical standards useful to the make the production system largely independent of region-specific characteristics and thus to guarantee an internationally constant quality. All these data and information were collected, summarized and incorporated in the general franchise manual and approved by the management board for implementation.

5. Conclusions

In this paper, a conceptual approach for the design of a scalable modular production system derived from a careful analysis of the industrial case of a two-stage food service franchise system was presented. The proposed concept is designed to ensure the capability of a production system to allow a fast and efficient adaptation to the continuously changing environment. It starts from a design framework which has three levels: (1) the design level, (2) the planning level, and (3) the execution level with their interactions driven by control loops between the levels that trigger a continuous re-planning respectively redesign of the system. Special attention is given to the design level, where a mechanism for the design of a scalable modular production system is presented: based on design rules provided by consolidated scientific knowledge and proved by best practice reports, so called standard production modules are designed along a scalability model. With this standard units, production systems can be easily assembled according to a set of requirements such as volume and product mix forecasts. A strict separation of region-specific cost factors (facilities, personnel) and region-independent cost factors (machines, equipment) facilitates also the calculation of different region specific business cases. Finally, the Central European market was selected as a case study region to verify the model using market scenarios.

The analysis of this industrial case showed a concept and mechanisms that were successfully applied in practice. "Well-grounded knowledge production begins with active observation" (Fawcett and Waller, 2011, p. 4): Especially in production and supply chain related research, a close contact with practice is very important to pursue the right questions and thus to produce insights that are both of high practical and scientific relevance. Of course, the results of a based on a research single case study cannot be generalized because it does not deliverreliable information about a broader class. The risk is that the theory describes – in very detail – but, however, only a very specific phenomenon. Despite this, the results of case research can lead to new and creative insights, the development of new theories, and have high validity with practitioners who are the ultimate user of research (Voss et al., 2002). However, case to obtain a higher robustness of the theory, qualitative case study research should be iterated with methods of quantitative research. Thus, further research will have to refine the presented concepts and to evaluate their generalizability by the analysis of a larger number of cases.

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