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Published in:
Procedia CIRP

DOI (link to publication from Publisher):
10.1016/j.procir.2019.03.252

Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 81 (2019) 1065–1070

www.elsevier.com/locate/procedia

52nd CIRP Conference on Manufacturing Systems

Product and Process Variety Management: Case study in the Food Industry

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Abstract

The demands of consumers in relation to products and services is changing and the food industry is no exception. Traditionally, companies in the food industry develop new products through a long development phase that often involves high costs in relation to product development, prototyping and pilot production, which increases time-to-market. Through a case study conducted within a food manufacturing company, the challenges and potential of variety management is identified. The common denominator for these challenges is the lack of an established product domain, process domain and the interactions and constraints between the domains.

Keywords: process variety management; product variety management; food industy; mass customisation; changeable manufacturing

1. Introduction

With an increased product variety and complexity, the focus on addressing effective use of innovative enablers of change and variety management is essential. Product variety can offer the potential to expand markets, increase sales volume and revenues. This can be an effect of both being able to serve entirely new customer segments, but also being able to sell to existing customer segments at a price premium due to more customized product offerings [1]. However, this positive outcome is not always guaranteed [1]. Offering additional product variants can lead to an increase of expenses from product design to production, inventory, selling and service. Therefore, defining the correct range of variants of the product that meets the customers' demands becomes a key issue in variety management [2]. The foundation of an effective variety management approach is avoiding "re-inventing the wheel" every time a new variant of the product is launched, both in terms of product design, manufacturing processes and raw materials [2]. In addition, taking a modular design approach in variety management of the product and process designs can reduce both complexity and cost [1].

Substantial research has been published within product variety management or within complexity management, which is a somewhat broader discipline than focusing exclusively on the variety of products [3,4]. A number of different methods have been introduced for analyzing product variety in order to consolidate the existing product portfolio of a company using either Product expert modelling or data driven analytics approaches [1,4,5]. Additionally, product variety management strategies have been categorized as being related to design, planning, and manufacturing ranging in scope from parts and products to the entire enterprise and markets [1]. Examples of such variety management strategies include modular product architectures, product family design, parametric design, group technology, delayed differentiation, etc. [1]. However, the vast majority of research within these fields focuses on discrete products, in particular durable goods and capital goods. When analyzing the variety of these products, central aspects include

10.1016/j.procir.2019.03.252

the number of different components, modules, subassemblies, different elementary operations in manufacturing systems, etc. These are, however, concepts, that do not directly exist in the process industry or the food industry in particular. Hence, the existing research on product variety management does not appears to be directly applicable within these industries. For instance, in practice, many durable goods manufacturers have managed product variety through postponement, delayed product differentiation, and by making, finishing, assembling, labelling and packaging-to-order [2]. However, process manufacturing is of nature more inflexible and fixed and postponement and delayed product differentiation is a difficult and sometimes impossible task [6]. Moreover, with the inflexible setups in the process industry and the introduction of reduced order sizes, significant challenges in the areas of planning and production control occur [6]. Few contributions from previous research address variety management within process industry, e.g. utilizing SMED for changeover reduction [7]. In addition, a minority of these cover variety management in the food industry. Some publications address how to apply product configuration to handle variety [8], or on the supply chain issues related to increasing variety in food manufacturing [8,9], however general insight into how to conduct process and product variety management within such manufacturing settings is not widely addressed, and limited practical guidelines for its application, challenges, and potentials remains.

Based on the current literature documenting research as well as practitioners' state of applying product variety management within the food industry, it can be concluded that additional research is indeed necessary to be able to realize the same potentials in product variety management, as are seen in other industries.

1.1. Research Question

This research presents a case study conducted within a food manufacturing company, with the aim of investigating challenges and experiences on product and process variety management in the process industry. Moreover, the research seeks to evaluate the potentials of implementing initiatives of product and process variety management in the food industry. The following research question is formulated:

What are challenges and potentials in the food industry when adopting initiatives of product and process variety management?

2. Method

To address the research question stated in Section 1.1, a case study is conducted within a Danish food manufacturing company. The case study research methodology is selected due to the explorative nature of the research question and the need for analyzing the phenomenon of interest, i.e. product and process variety management, not in an isolated manner, but rather in its specific context, i.e. the food manufacturing industry [10,11]. Thus, the case is selected based on theoretical replication logic, and the ability to obtain in-depth knowledge of the research challenges and potentials specific to food manufacturing when adopting initiatives of product and process variety management. In Section 3, the case company is introduced.

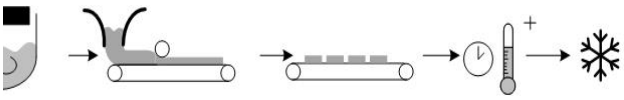

Fig 1. Manufacturing process at the two lines at the case company.

For the case study, data and information were collected over a period of 14 months, where a variety management project took place in the company. This project involved several stakeholders such as product development, category managers, production management, sales, and quality. In the project, one of the authors also participated and field data were collected through participation, observation, and interviews, supported by additional archival information, such as historical data, internal presentations, internal documents, etc. These different sources of information collected within the case company were analyzed to identify challenges and potentials in product and process variety management specific to the context of the case study.

3. Case

The case study was conducted in a Danish manufacturer of bread and pastry. The company has an annual revenue of 1.7 billion DKK and take on 1,400 employees. The variety management project investigated for this research focuses on two production lines in a Danish site that produces a diverse range of Danish pastry. Fig. 1 illustrates a generic flow of the case company's production lines, which includes the following activities: 1) mixing and processing of dough, 2) rise and relaxing of the products, and 3) freezing.

In the last 10 years, the case company has experienced significant changes in the market demand. One aspect of this is the order sizes. The distribution of the order sizes related to the

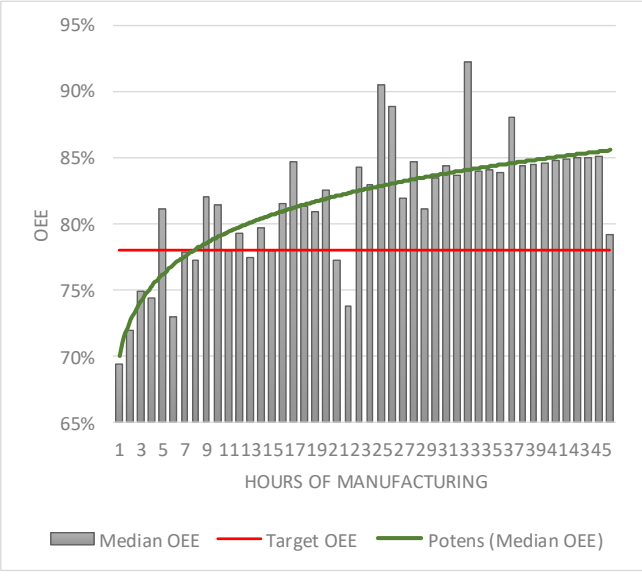

Fig 2. The OEE of the production correlated to the length of the batch runtime.

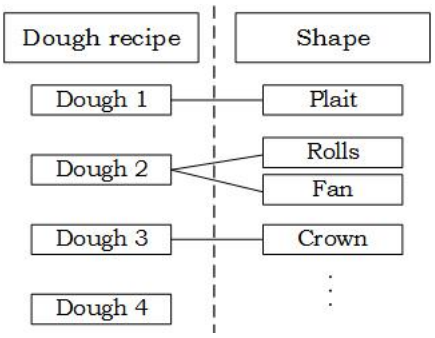

Fig. 3. The relation with dough and shape today.

Overall Equipment Efficiency (OEE), which is illustrated in Fig. 2. The OEE in this example is only related to the average utilization of the equipment for a production order from start to end. Quality loss of products is not included in the analysis, as this data is not present in the case company. The case company has a target on OEE of 78 percent. From the figure, it is evident that having production runs longer 7.2 hours is needed for the case company to fulfill this target. Nevertheless, the order size have been reduced from 8.6 hour in 2013 to 7.5 hour in 2017, and no indications of change in this decreasing trend are evident, since the food market in general increase the level of customizable products. The main reason for the decreasing OEE operating with smaller production runs is the changeover time, which consists of both cleaning from a previous batch and adjustments to the following batch. These many adjustments made by the operator are linked to a cognitive complexity, because of many undocumented process uncertainties in the production system. Product development face similar challenges with complexity. As an example, in the case, one dough recipe is linked to one or two shapes, see Fig. 3. However, the effects of using one dough to all shapes are relatively unknown. Thus, far from all the interfaces within the product are established and well-known, which results in significant complexity in the design of new products. Consequently, it takes around a year to design a new product.

4. Challenges and Potential

From the case study, several challenges and potentials where identified in regard to variety management. In the following, challenges representing significant relations to process and product variety management are explained in detail. The approaches applied in the case company towards solving these challenges are included as well. Evidently, some of these approaches are not solely related to process and product variety management, but apply more generally to operations management and operations improvement. However, in the process of implementing a process and product variety management in the case company, these described solution approaches were identified as particularly relevant and as a foundation for process and product variety management.

A summary of these challenges and potentials are listed in table 1.

4.1. Point of product differentiation

Delaying the point of product differentiation is an effective means of addressing product variety. The nature of the process utilized in the case company results in difficulty in delaying the point of product differentiation. In some areas within the case company, delayed differentiation is simply an impossible task. The task is difficult because the differentiation happens in the mixing process before the process becomes discrete. Furthermore, the semi-manufactured products cannot be kept

Table 1. The challenges, approach and potential identified at the case company.

Section	Challenges	Approach	Potential
4.1	Changing the point of product differentiation because of the nature of the process industry	Three archetypes, of the dough recipes, was uncovered by a study of similarities and tests by a tasting panel.	Save time and reduce manufacturing process complexity
4.2	As a result of tacit knowledge and lack of process stability, all tests must be carried out on the production lines.	Study the process and the raw material by test in a lab equipment.	Reducing the time to market and specification of raw material for the supplier.
4.3	Due to the nature of the product, there is no standard interfaces between parts of the product. The production is solely operator driven and lacks waste transparency.	Adding sensors to the production facility and modify the manufacturing process to a more digital setup.	A uniform quality of the products. Data driven process variety control. Reduce time to market.
4.4	Missing of translating the customer requests to parameters of the product and process. Not exploring the benefits of applying a product family.	Take part in several projects with universities and other food companies to develop examples and knowhow.	A better customer satisfaction, stepping into new markets and reduce time to market.

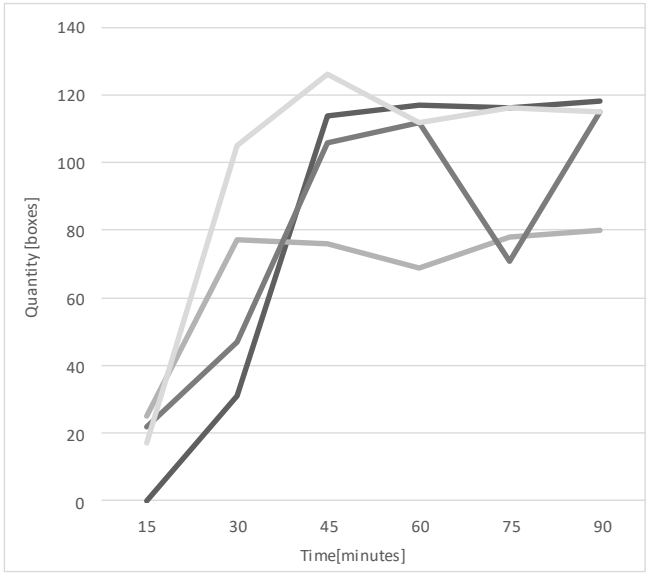

Fig. 4. The first two hours of the product flow then only changing the dough recipe.

in stock in order to make the customization later, since the products decay. To change the point of product differentiation, the existing dough variety is studied. From the nine dough recipes, three archetype dough recipes were discovered. The three archetypes were identified by a study of similarities of the nine currently used recipes. The amount of gluten was the primary driver for differences in the dough recipes. However, a tasting panel representing the end customer supported the assumption of three archetype recipes.

There is a time saving potential when reducing the number of dough recipes. This potential can be derived from Fig. 4, which illustrate the amount of boxes of products produced every 15 minutes starting when there is a change in dough. The graph only takes into account the changes in the dough. However, in addition to this, it is possible to change shape, filling and topping, which is not considered here. Therefore, the graph only represents the effect of the change of dough. Fig. 4 illustrates a ramp-up phase. Evidently, 15 minutes into the production, between 0-20 boxes have been produced. Moreover, 30 minutes into the production, the output increases and one can assume that there is stabilization at 45 minutes. Fig. 4 illustrates a clear ramp-up phase. Therefore, by reducing the variety of the dough recipes, time is saved in production. Moreover, the manufacturing process complexity will be reduced because of the number of equipment adjustments needed. The potential can be obtained without having a visible effect for end-customers.

4.2. Testing

The different additives and the amount of ingredients determine the property of the dough and the settings of the equipment. However, the knowledge of the production processes and the correlation with the ingredients in the dough is lacking and tests have to be performed in the production setup. It is not only the recipe of the dough that needs to be tested, but also the dough recipes' effect on different shapes, number of layers of lamination, and the amount of rework of the dough. These effects are not documented in the case company, which results in significant testing. During the project, around 25 tests have been performed; corresponding to 2500 kg test dough. The case company estimates that about 40 more tests are needed before the number of doughs can be reduced with 40-50 %. It is not only recipes and the settings of equipment that need to be tested before a variety standard can be established. The quality of the raw material affects the production processes and thereby the products. Tests of the raw materials are performed at the supplier and the magnitude of these effects on the raw materials are unknown within the case company. Additionally, testing becomes an even bigger task, when taking into consideration the fluctuation properties of the raw materials.

To accommodate the challenges of testing and determining the effects of the raw material, the case company have involved in a large-scale project that includes initiatives outside the case company and invested in lab equipment. The lab equipment represents three steps in the manufacturing process: mixing, extruding and raising. The procedure for the lab test is to mix the dough under a controlled environment and thereafter blow a bubble in the dough, like a balloon. The time that it takes to burst the balloon and the tension in the dough are measured. By representing the dough in the lab environment, tests in the production can be reduced and additionally, time to market for new products or sub products can be reduced. Furthermore, by making tests in the lab environment, it is possible to identify and specify the raw materials, thereby, making specification for the supplier and giving a co-responsibility for the quality to the supplier.

4.3. Standard product interfaces and cognitive complexity in the production setup

The variety management of the dough recipe is only a part of the task of the Danish pastry product. A Danish pastry often consists of a dough, a shape with a filling and a topping. There are no standard interfaces between these parts of the product. The product cannot be viewed as a mechanical assembly of parts, i.e. if changing one parameter or part component, the effect on the end-product is unknown. Furthermore, the production process is today solely operator driven. Thereby, cognitive complexity exists in the case company. This creates challenges in terms of product and process variety management and makes the case company vulnerable and less competent in reacting to the market, as the effects of introducing new products and processes are unknown. Moreover, the case company experiences challenges with costing of products due to lack of waste transparency. The physical waste is not logged per product, which results in not knowing the product cost to produce. In conclusion, the case company is lacking information of the product performance in production. To comply with this challenge, a more digital and transparent production setup is the objective. In addition to the variety management project, several initiatives were conducted in the case regarding transforming the production process from solely operator driven towards a digital data driven production. Sensors have been added to the production facility, as well as

new logs of the PLC's setting. The first step is to define the standard parameters and find possible placebo adjustments of parameters.

The potential of establishing the standard parameters is a better quality of the products. Moreover, a data driven understanding of the manufacturing process variety. In time, the boundary of the process solutions space can be mapped and the time to market can be reduced.

4.4. Awareness

The product development setup, at the case company, consists of a team that develops new ideas for products by trying to find a new variant that the customer likes and is producible. From an idea of a new product to the commissioning phase, it takes around one year. At the case company, it have been a challenge to translate the customer requests to parameters of the product and process. As a result, the process variety and the product variety are not closely linked with the customer wishes. Finding a systematic way of establishing the product and process variety which encompass the customer requests, have not been in focus at the case company. The company does not reap the benefits of having a product family even though the durable goods industry have seen good results. Nevertheless, exploring the benefits of applying a product family has not been prioritized. One of the reason for this prioritization is the lack of examples from the process industry.

To accommodate the changes of little examples and knowhow, the case company have engaged in several projects with universities and other food companies. The potential of these initiatives is a better customer satisfaction, stepping into new markets and reducing time to market.

5. Discussion

This research concerns the challenges and potentials that one food manufacturer faces, when seeking the benefits from product and process variety management. The method applied for this research is solely based on one case study of two production lines producing Danish pastry and further research is needed to generalize. The research presented in this paper, extends a previous contributions by the authors, where a survey of 18 food production lines were performed, reviling that the product variety challenge cannot be met only by improving planning and control, but rather requires the food manufacturers to adopt more changeable production equipment [12]. As a continuation of this survey, this paper had the aim of exploring challenges and potentials of utilizing product and process variety management within a case company. However, this case study has not exhausted the subject of methods and strategies applied to reach potentials in terms of improved product and process variety management and challenges still remains within the area. Thus, future research needs to focus on how to adapt well-know strategies on product variety management and process variety management to fit the characteristics of food manufacturing.

For instance, the case company and the findings of this research do not include aspect of machines and the physical setup to reach higher levels of changeability, flexibility, and reconfigurability. In fact, the potential in addressing this is likely to be larger than this research outlines. As stated in section 1, rather limited research is published on product and process variety management in the food industry, and in the process industry in general. Moreover, little research has been published on mass customization and changeable manufacturing for the food industry. In particular, little research in respect to significant guidance, or even identification of both design opportunities and constraints [9]. McIntosh et al. [9] argued that one major factor in a general lack of pursuit may be the differences to be faced between food products and mechanical products. The challenges outlined in this research all point to an undefined product domain and manufacturing process domain and the relationship between these, which challenges the applicability of already existing methods and knowledge on product and process variety management. For instance, Abbas et al. [13] suggested a framework for the co-development of products and production systems and defined them as co-equal objects with interactions, interfaces and subsystems. Moreover, other well-known strategies, techniques, and tools for product variety management must be reconsidered within the food industry, and process industry in general. By not having a modular product setup, this research documents challenges at one food company faces when seeking to define the product domain, process domain and the interactions and constraints between them. As a future research area in terms of accommodating these challenges is to apply a more data driven production. Thereby, it is possible to obtain more information on the two domains and constraints between them.

6. Conclusion

Offering additional product variants can lead to an increase of expenses from product design to production. Therefore, by the variety management approach the manufacture can avoid "re-inventing the wheel" every time a new variant of the product is launched. The process industry or the food industry, have not seen directly applicable research on product variety management. Therefore, this research addresses the challenges and potentials in the food industry when adopting initiatives of product and process variety management. A case study is selected based on theoretical replication logic and the ability to obtain in-depth knowledge. The case company is a Danish pastry manufacture and produces with a continues- and discreet-process flow. The challenges and potentials are listed in table 1. The challenges are not only relevant in regards to product and process variety management. However, the case study identify that the challenges are the key to managed product and process variety management in the food industry. The common denominator for these challenges are not having an established product domain, process domain and the interactions and constraints between the domains. Lifting the level of information of the production system can be carry out by utilize sensors in the production.

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