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Complexity management in the food industry

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COMPLEXITY MANAGEMENT IN THE FOOD INDUSTRY

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Abstract

The many stakeholders in the food industry with their diverse interests make this industry complex and interesting to work with. There are four main stakeholders; 1) The customers with their increased demand for customized products, quick delivery times and increased responsiveness, 2) The authorities with increased legislations, 3) Employees with salary demands and 4) Owners/shareholders with profit wishes add to the complexity. Furthermore, markets are getting bigger and the competition harder. The profit margin for many companies is getting smaller. There are a demand for quantifying this complexity and finding a method for using these complexity factors in economic calculations. The research question this paper seeks to address is therefore "Which complexity factors can be quantified in the food industry and how can they be used in economic calculations?"

A case study of a SME Danish bread producer will address the research question due to the explorative nature of this study and the limited amount of previous research within this field.

Keywords: Complexity management, complexity costs, Wasted Time Cost, Wasted Products Cost, Inventory Costs, ABC analysis.

JEL classification codes: L10, L11, L23, L60, L66.

1. INTRODUCTION

Supply chains are being increasingly large and complex, often spanning the globe and involving thousands of enterprises. At the same time products have become more customizable and manufacturing systems are designed to be more flexible (Perona and Miragliotta, 2004). This complexity can be costly due to increased administration, overhead and lack of clarity. However, companies are increasingly pressured on cost and time to market. Companies there need to manage their complexity in order to lessen the costs associated with it. To do so complexity needs to be quantified in order to determine how complexity impacts each stage of the supply chain, including production, warehousing and transportation. The impact on lead time, cost, quality and productivity that offering greater product variety in more product sites has is therefore vital as organizations need to determine the true cost of complexity while optimizing production without jeopardizing service level to customers.

While there have been many different definitions of complexity depending on the context this paper adopts the view of complexity as the number of unique products in the product offering, also called the product portfolio complexity (Closs et al., 2008).

Companies in the baked goods sector are facing many pressures which require the most efficient operations in order to remain competitive. Such pressures include higher labor costs, increased price competition, increased demand for customized products, and demand for quick delivery times and increased responsiveness (Higgins, 2013). These trends hold true in the baked goods sector within Denmark, as well. Companies within the grain, milling and baking sector in Denmark have undergone changes in the past five years as the number of manufacturing enterprises has declined by 28% and the number employed in this sector declined by 18% in the same period (Danmark Statistik, 2015). From a financial perspective, the companies in the baking sector are performing better. The profitably of this sector has grown substantially by 63% in the past five years despite annual turnover decreasing slightly by 5% (Danmark Statistik, 2015). These statistics show that baked goods manufacturers are restructuring themselves to produce more with less resources and that fewer companies are able to successfully respond to the changing customer needs in the current market.

The baking industry faces customer depend for increased flexibility and responsiveness, yet need to keep cost low (Pinedo, 2009). Such costs include the cost to hold products in inventory, labor costs, machine costs, scrap material costs and the cost change over from one product type to another, which can vary depending on the sequence of production. Other aspects of the baking sector that complicate production are the presence of active yeast in the dough, the multi-stage fermentation process, handling of allergens and organic ingredients and the use of large, capital-intensive production equipment which requires long setup times (Modal & Datta, 2008; Akkerman & Van Donk, 2009a; Akkerman & Van Donk, 2009b). To meet the needs of both customers and production, complexity needs to be quantified and managed.

However, complexity management in the food industry is not well-researched.

The research question this paper seeks to address is therefore “Which complexity factors can be quantified in the food industry?”

A case study of a SME Danish bread producer will be used to address the research question.

The paper is structured as follows; first a literature review is detailed followed by the methodology. The findings and analysis of these from the case company is then presented, followed by a discussion of these. Finally, implications on theory and practice of this research and a conclusion is detailed.

2. LITERATURE REVIEW

2.1. COST MANAGEMENT IN THE FOOD INDUSTRY

The competition on the international food market is increasingly rough. It is therefore of vital importance that management is able to identify cost structures for a production to justify new initiatives and for being competitive. The structure should be efficient and transparent. It should identify carriers of cost and places of cost. Bogdanõiu (2012), present a method for cost calculation in the dairy industry and point out the importance of identifying the different elements in the cost structure. In order to get an efficient cost structure lean could be used as a tool. Lean is a value adding and waste reducing method. Ma and Zhan (2014) present a cost management method using lean. They focus on the total logistic chain and divide their analysis into an external and an internal cost management analysis. The two stages are analyzed separately with different optimization carriers. As markets are getting bigger together with increased customer demands many companies offer product varieties. This product variety influences the cost structure. Mogens Lund et al. (2004) present a cost structure for producing food products with different quality parameters.

2.2. COMPLEXITY MANAGEMENT

Today it is unconceivable for companies who provide mass consumer goods not to propose several variants of their products. Companies propose a very large panel of product variants: colours, size, type of raw materials, logistics, design and so forth as a result of differentiation strategies to

achieve higher revenues and market shares (Tang, 2006).. As a result, the recent "variety drives growth" model is challenging for most industries (Mahler & Bahulkar, 2009).

However, offering so many product varients in one’s product portfolio can be costly due to the fear of product “canibalisation”, increased resources used on logistics, production, production planning and scheduling, difference in raw materials, products serviced by customer service etc. – all with a decrease in revenue to follow (Mahler & Bahulkar, 2009; Hansen et al., 2012; Schaffer, Schleich, 2008; Lovejoy & Sethuraman, 2000).

Complexity management is therefore about balance (Quelch & Kenny, 1994; Lindermann & Maurer, 2007); operations management on one side that wishes to reduce complexity as much as possible in order to gain efficiency and sales and marketing on the other hand which wishes to offer as much choice as possible in order to attract customers (Perona & Miragliotta, 2004).

This balance when it comes to product variety is often a balance between removing underperforming products – also called "tail-cutting" - from the product portfolio and focus on current market winners and “betting” on new or slow moving products for long term gain (Mahler & Bahulkar, 2009).

Complex comes from the Latin complexus which means "embrace". The expression complex deals with an indecomposable action unit, which means that it could not be taken for a single element. Only a system could be seen as a complex unit and thus, “complicated” and “complex” are not similar in the production industry (Tarride, 2013).

A key element of a complex system is the intimate connections between its different parts which makes it complicated to understand as breaking it down into individual units would hide the interactions (Perona & Miragliotta, 2004; Tarride, 2013).

Complexity can be found in all aspects of an organisation. Sivadasan et al. (2006; 2010) investigated two kinds of complexity in a supply chain, structural and operational complexity. The first one increases with the number of elements and the second focuses on the uncertainty of information and flows (Lindermann & Maurer, 2007). Wilson et al. (2010) investigated three dimensions of complexity: product complexity, process complexity and organizational complexity.

In this paper we focus on product portfolio complexity due to the characteristics of the food industry where product variety is essential. We use the definition by Closs et al. (2008), which states that “product portfolio complexity management is defined as the collective set of decisions, supporting processes, value systems and initiatives to determining and implementing the most effective product portfolio (i.e. mix of variants, feature sets, and component choices).”

Several methodologies are described in literature on the management and measurement of product

complexity; these can roughly be divided into two main groups (Budde et al., 2015); 1) Monetary evaluation concepts which focus on the complexity costs of product variants (see for example Lechner, 2011 and Schuh & Schwenk (2001)) and 2) Non-monetary concepts to evaluate the product related complexity by building indices (see for example Orfi et al. (2011, 2012)). This article takes a momentary approach. Within this approach there is a lot of focus on “tail-cutting” methods; motivated by research which has shown that there is no relation between the number of stock keeping units and market share (Hansen et al., 2012). Methods for “tail-cutting” are introduced in the following.

2.3. ABC METHODOLOGY

Based on the Pareto principle an ABC analysis makes use of a mathematical statistical method in order to grade different products of a company to A, B or C level. These three levels are used to implement the appropriate management on the classified products. Each level refers to a proportion of the number of products in the company and to the total amount of revenues it brings to the company as follows (Liu & Wu, 2014):

- Level A products should be 5%-15% of the total number of products but bring in 60%-80% of the total revenue;
- Level B is around 20%-30% of the total number of products and also account for 20%-30% of the proportion of the total amount of money brought back to the company;
- Level C refers to the majority of products 60%-80% but brings only 5%-15% of the company's revenue;

An ABC analysis can aid in deciding on degrees of control, devices configuration, orders quantity, ordering methods, way checking, statistical methods and insurance reserves for each product as these often will differ depending on the product's classification (Liu & Wu, 2014).

It should be noted that also customers can be classified according to this scheme; e.g. the majority of sales often comes from a few important customers while a non-significant part of sales is due to a large number of small customers (Chen et al., 2006).

2.4. COMPLEXITY COSTS

"Cost of complexity" refers to the potential wasted money a company uses to maintain performance of heterogeneous groups of tasks. Complexity costs in regard to product portfolio management refers to all costs the company has related to the handling, management, creation or producing of any variant of a product (Schaffer & Schleich, 2008).

There are two main reasons to calculate the complexity costs of a company's product portfolio: in order to be able to behave reactively and proactively in regard to portfolio management (Lindermann & Maurer, 2007). Another reason is that calculating complexity costs makes it possible to share them with suppliers and partners. Furthermore, knowing complexity costs enables improving processes as it then becomes known which part of the process creates more waste (Anderlini & Felli, 1999). Furthermore, in order for a production company to apply lean manufacturing it needs to be aware of its complexity costs in order to minimise these while keeping a balance between increasing variety costs and providing more products in the market which means increasing revenues (Schaffer& Schleich, 2008; Lancaster, 1990).

Several complexity costs exist. Lovejoy and Sethuraman (2000) for example, choose to focus on four categories: labour, material, indirect variable costs and warranty costs. Main causes of complexity costs have been identified as time and quality. However, it should be noted that quality issues could have an impact on time-related issues. Time-related issues include issues relating to additional machine setups, information-system delays and other non-productive time which contribute to complexity costs. In addition, if a product variant which needs less production time, a qualified worker would be paid to wait for the next product and this wasted worker time has to be seen as a complexity cost as well. In other words, idle times are one source of complexity costs (Schaffer, Schleich, 2008). Furthermore, an important factor of both quality and time related issues are human error (Lovejoy & Sethuraman, 2000). As a consequence, rushing – in order to be more productive or to correct wasted time – is not an appropriate behaviour. Indeed, it will lead to a lower level of time spent on a task but it also increases the probability of producing defective products.

Another category of complexity costs is non-value-adding costs (Scheich et al., 2005; Schaffer, Schleich, 2008), in include the following costs: sequencing costs, downtime costs, line balance & waiting time costs, walking time & transportation costs, set-up costs, storing costs, costs of stock-outs, part selection and walking time costs, rework costs, scrap costs, data maintenance costs, data handling costs, production planning costs and controlling costs.

Other complexity costs relate to the whole life of the product (Hansen et al., 2012). Hansen et al. (2012) have introduced Life Cycle Complexity Factors (LCCFs) to find the asymmetric cost distribution across the product variants. Hence, some resources are not equally divided for each product variant which is one cause of complexity cost.

Today, companies often have a lack of transparency in calculating complexity costs across the product portfolio. Decision makers have to make the right decision without knowing the exact profitability of each product variant. Another fuzzy point is the lack of information about the impact of each product variant on global indirect costs (Lindermann & Maurer, 2007). Knowledge of complexity costs is the key to a better production cycle, but any complexity cost function should consider the specific parameters and characteristics of the given company (Anderlini & Felli, 1999).

3. METHODOLOGY

The research focuses on understanding and calculating complexity costs in the baked goods industry. The research will use a qualitative approach in order to explore the research question and provide rich, deep data (Oakley, 1999). A quantitative approach is used afterwards to analyse the dataset. The explorative nature of the research question allows for an in-depth understanding of the research area which makes the case-study approach the most appropriate research methodology (Yin, 1989).

The research includes three key phases: a theoretical phase, an empirical phase, and a reflection on current theory based on new empirical evidence. First, an extensive literature review was carried out. Second, data was gathered from the case study and these findings were used to reflect on the current situation in the research field. Finally, the theoretical and practical implications of the new knowledge were identified.

The main method of data collection was through company visits, interviews, presentations by the senior staff and documentation. The documentation includes company archival documentation, strategy documents and public statements. The method ensured accurate representation and enabled triangulation of the findings between different sources of information thereby improving validity (Mason, 2002).

In details, this is the precise description of the methodology used in the study case. It is based on the five steps proposed by Hvam in 2010 and was adapted for the research.

- Define the scope of the products and processes to include in the analysis;
- Initial ABC analysis of products;
- Identification and calculation of the most significant complexity costs;
- ABC analysis of products based on complexity costs calculation;
- Identification and quantification of possible initiatives for complexity costs reduction;

3.1. THE CASE COMPANY

The case company, called Food A/S for the sake of anonymity, is one of the biggest bakery providers in Denmark. In 2014 the company reached a turnover of EUR 26.6 million and currently it employs 130 people and provided 8 countries worldwide with more than two hundred products.

Over the past few years the company has increased the number of products in its portfolio but as a result of the high demand Food A/S has almost run out of production capacity. To stay competitive in this tough market, the company has to deal with complexity in its production process which was why the company was selected to be used as a case study.

3.2. DATA COLLECTION

Data collection was performed through several visits to the case company. Qualitative data was collected by six interviews with production managers and sales employees. All interviews were semi-structured and lasted 1 hour. The interviews were recorded and transcribed.

To gain data triangulation and a more holistic picture of the company, the analysis also made use of annual reports, internal communication documents and descriptions of work processes. All sources were provided by Food A/S and came from its ERP system. Documents used included: cost distribution and structure from 2014, sales statistics from 2014, production statistics from 2014, stock level from 2014, expected and real stock level from 2014. Furthermore, internal communication documents and descriptions of workflows and processes were used. In total, 92 traded products and 163 produced products were analysed. These products represented 98.5% of the products offered by Food A/S.

4. COMPLEXITY COST CALCULATIONS

This section introduces the key complexity cost calculates used in the analysis of the case study,

As described in the literature review, time is one of the parameters of complexity in a production line. During production, there are two main sources of wasted time: necessary changeover of machinery between the production of two different products and production stops due to machine or human error. In this article changeover time is considered product specific and depends on product features and on the production sequence. In Food A/S the production schedule is designed in order to minimize this waste between two production processes. Wasted time due to machinery stops is also considered product dependent because the more complicated the product is, the longer the stops are assumed to be.

The cost of these wastes of time is WTC (Wasted Time Costs), and can be calculated for each product as WTCi.

The Wasted Time Ratio (WTR) is the ratio between no-worked time and total production time. Here, Downtime means all stop times: changeover ones and production stops from 0 to m. TotalProductionTime refers to the total amount of time when the company is producing.

$$WTR_i = \sum_{n=1}^{m} \frac{Downtime\ n}{TotalProductionTime} \qquad (1)$$

The sale indicator SI is used to indicate the amount of sold products compared to produced products.

$$SI = \frac{SoldProducts}{ProducedProducts} \qquad (2)$$

The Time Wasted Cost for the amount of sold products is calculated as followed,

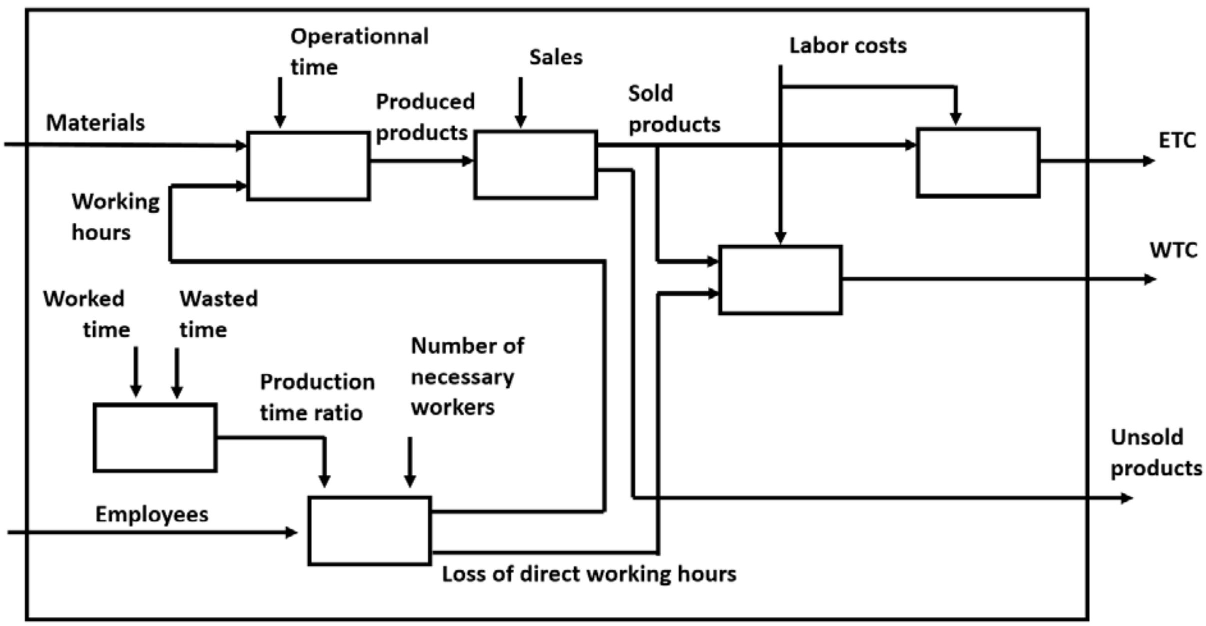
$$WTC_i = SI_i . WTR_i . OT_i .\ W_i . LC_i \qquad (3)$$

It considers the amount of wasted time and used costs of the production line by the unit of time used for each product. In the formula the following symbols are used:

- WTR_i is Wasted Time Ratio, introduced above;
- SI_i is the Sale Indicator for each product, introduced above;
- OT_i is the Operational Time for each product;

- W_i is the Number of needed Workers in the production line for each product;
- LC_i is the Labour Cost by time and worker unit;

The calculation flow is shown in figure 1 where ETC is the Effective



Time Ratio. This formula does not consider the amount of unsold products, which is an added production cost. Figure 1 show a graphical representation of this calculation.

Figure 1. *Detail of Wasted Time Cost calculation*

Product Waste Cost (PWC), another complexity cost, can be calculated for each product in the product portfolio and consist of two elements, Wasted Ingredients Costs (WIC) and Wasted Products Costs (WPC). The Wasted Ingredients Costs (WIC) refer to the not finished products which are wasted – such as dough that in our study case is named ingredients. The other element, Wasted Products Costs (WPC) refers to the final products wasted due to poor quality. Formulas are based on product and ingredients weight and therefore almost all costs are given by kilogram.

The Wasted Ingredients Costs (WIC) for each product (i) can be calculated as

$$WIC_i = IW_i \,.\, CSP_i \,.\, SI_i \qquad (4)$$

where IW is the weight of ingredients or semi-finished products waste, CSP is the average cost for 1 kilogram of ingredients or semi-finished product and SI is the sale indicator.

The Wasted Products Costs (WPC) can for each product (i) be calculated as a cost by kilogram which is multiplied with the total weight of sold products

$$WPC_i = FPW_i \,.\, \frac{PC_i}{WE_i} \,.\, SI_i \qquad (5)$$

where FPW is the weight of final products waste, PC the total production cost of the process, WE the weight of the final product and SI the sale indicator.

It should be noted that WIC and WPC are named “costs” in this article because they belong to complexity costs but they shouldn’t be understood that way. Indeed, they are neither predictive nor repeatable, so instead of costs, they should be taken as the amount of money the company paid for each product.

The Product Waste Cost (PWC) is the sum of WIC and WPC and illustrated in figure 2.

$$PWC_i = WIC_i + WPC_i \qquad (6)$$

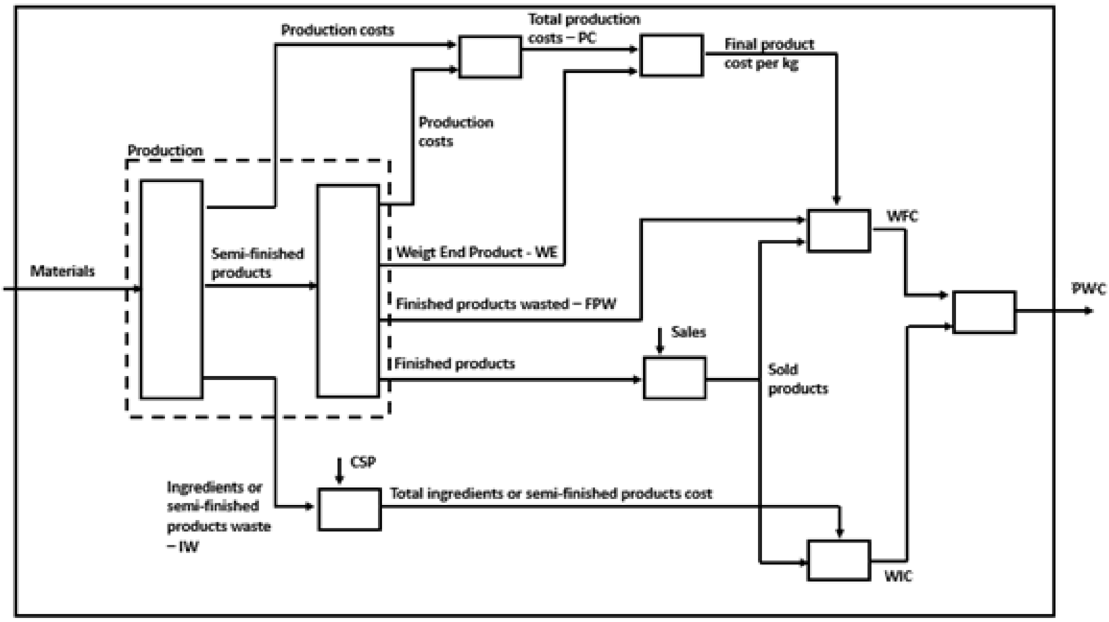


Figure 2. *Detail of Wasted Products Cost calculation*

Inventory is another important issue in food industry due to the perishable nature of the goods and the fact that many needs require detailed temperature control. A formula that permits calculation of the inventory rent and handling costs is introduced. As almost all companies in this sector deal with pallets of products, pallet is used as a product unit.

The inventory renting and handling costs (IRCH) for each product (i) can be calculated as:

$$IRCH_i = \sum_{T} \left(SC_t \cdot \frac{IL_{Ti}}{IL_T} \right) \qquad (7)$$

where SC is the storage cost per unit of time, ILTI the inventory level per unit of time for the chosen product, ILT the total inventory level per unit of time.

A challenge for the food industry is as mentioned the perishable nature of the goods. Therefore, an additional complexity cost is introduced; the cost of wasted product due to an early expiration date.

The expiration costs (EC) for each product (i) will be calculated as,

$$EC_i = PW_i.V_i + (ES_i - AS_i).V_i \qquad (8)$$

where PW is the number of pallet wasted due to expiration date, V the value of one pallet, ES the expected number of pallets in storage at the end of the period of time and AS the actual number of pallets in storage at the end of the period of time.

It should be noted that the difference between expected and actual number of pallets in storage refers to products near the expiration date and sold to local shops at a discounted price. As the price just covers logistics costs, incomes could not be considered as net revenue.

5. ANALYSIS OF THE CASE COMPANY

The salary for a production worker at the company is about 30 Euros. In order to better understand the cost impact, the ratio of Wasted Time Costs over the net revenue provided by the product is calculated. For each product, Wasted Time Costs contributes from 1% to 56% of the net revenue but only 3 products have a ratio higher than 20%.

To check the relevance of the formula, the total labour costs given by the company, the direct labour costs found by the methodology and the Waste Time Costs are compared. Results are presented in the followed table (in DKK).

Table 1. *Allocation of labour costs, in DKK.*

Type	Direct Labour Cost	Wasted Time Cost	Total Labour Cost
Total	27 778 170	5 878 299	34 108 478
Allocation	81.4 %	17.2 %	

As indicated, 98.6 % of total labour cost has been allocated in Direct Labour Cost and Wasted Time Cost. The little gap between total labour cost and the previous sum is due to the data fluctuation previously mentioned. This gap is considered as negligible and consistency of the formula is thus proved: the Wasted Time Cost formula could be applied to the case.

The Ingredient or Product Waste Cost was calculated as was the ratio of this cost over net revenue. Values of this ratio varied from 0.5% to 58% but as high values seemed not to be correct, the data source for products with a ratio higher than 30% was reviewed. The reasons for the disturbance for these values are illustrated in the next table.

$$RATIO = \frac{IngredientOrProductWasteCost}{NetRevenue}\ (\%) \tag{9}$$

Table 2. *Reason of Ratio disturbance for some products*

Product	**Ratio**	**Possible reason of inconsistent ratio**
Mini Snails	58 %	Similar value for all samples
Caramel Tang	56 %	Only one data sample
Organic chicken	55 %	Similar value for all 4 samples
Sandwich Square	41 %	Only one data sample
Pulled beef horn	36 %	Similar value for all 3 samples
Mini “gifler” (sweet roll)	34 %	Similar value per hour
Caramel croissant	33 %	One sample value seems too high
Sandwich	30 %	Similar value per hour

The products with unreliable datasets account for nly 3.4% of all produced goods in the investigated time period. The calculated ratio of all other products is therefore used because these results are consistent and the data source is reliable. The following table links Direct Material Cost, Ingredient or Product Wasted Cost and total Material Cost – all values are in DKK.

Table 3. *Allocation of material costs, in DKK*

Type	Direct Material	Ingredient or	Total Material

	Cost	Product Wasted Cost	Cost
Total	60 667 367	11 157 248	74 387 737
Allocation	81.6 %	15.0 %	

Food A/S is charged weekly for it inventory use which it outsources to a third party. The all storage service could be divided into several charges related to inbound and outbound warehouse operations, rent of storage space, splitting cost and all other costs. Details can be found in the next table; prices are in DKK.

Table 4. *Detail of renting costs*

Cost type	Amount	Share
Inbound operations	934 617	18 %
Outbound operations	666 324	12 %
Rent of storage space	2 943 359	55 %
Splitting cost	265 052	5 %
Other costs	524 624	10 %
Total	5 33 976	

The rent of the storage space is the most expensive cost among all handling costs for Food A/S.

Products with a close expiration date are sold to local shops and as direct sale to local customers at a discount price. This income isn't counted as net revenue and is just quantified in the inventory complexity costs by the company. Data about expiration costs wasn't clearly visible in the company's ERP system, so expected and real stock were used to calculate it as explained previously.

The following table show the products with the highest value of Total Inventory Cost (inventory rent & handling costs and expiration costs) over net revenue ratio. Net revenue is in DKK and quantity refers to the number of sold cartons in a year. As can be seen some products have an extremely high value.

$$RATIO = \frac{InventoryRentAndHandlingCost + ExpirationCosts}{NetRevenue} \tag{10}$$

Table 5: *Detail of high ratio products*

Product	Net revenue	Quantity	Ratio
Bread malt piece	1 120	28	514 %
Focaccia with olives	2 384	22	435 %
Nature bread	2 961	32	191 %
Olives bread	1 612	24	154 %
French hotdog	45 860	1 016	81 %
Mini gifmer	13 345	107	73 %
Precut Wholegrain Rosetta	68 833	588	73 %
Sandwich square 2	8 952	63	67 %
Hamburger bread	4 562	81	65 %
Crown	1 359	18	57 %
Sandwich Square 3	46 535	358	44 %
Whole Somun	50 102	468	40 %
Pizza roll	36 337	239	37 %
Organic mill field piece	25 243	163	36 %
Mine snegle	22 390	124	33 %
Organic Enghaven	25 620	165	32 %
Simit ring	12 283	65	30 %
Sandwich flutes	5 291	46	30 %

As can be seen from the table products sold in small quantities have a very high ratio of Total Inventory Costs over net revenue. This is because these products don't move a lot – as they are not sold very often – and they are therefore stored for a long time. For high quantity sold products, sales statistics given by Food A/S show that customer demands vary a lot.

In order to understand the Total Inventory Cost division, the following figure shows inventory costs distribution.

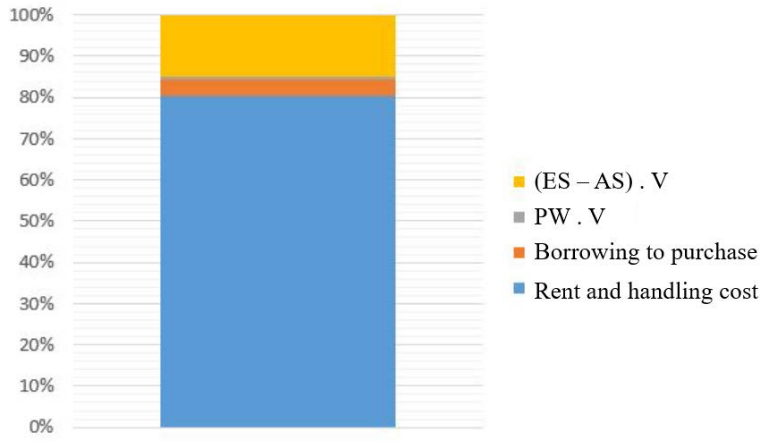


Figure 3. *Allocation of inventory costs*

The second important inventory cost is caused by discounted sold products. It should be noted that almost 15% of the inventory costs are due to product lost. Even if any share of this cost over net revenue exceeds 4% it is a big issue for Food A/S.

In the following table Total Inventory Cost for Food A/S is calculated and compared with the company given data. A gap of 21% can be observed. This is because Food A/S in their own calculations doesn't consider borrowing to purchase and expiration costs and these costs are around 20% of the total inventory costs. Costs are presented in DKK.

Table 6. *Gap between firm's calculation and research's one*

Food A/S inventory costs	**Formulas calculation inventory costs**	**Gap**
5 325 591	6 458 349	21 %

5.1. SUMMARY OF THE COMPLEXITY COSTS QUANTIFICATION

The main limitation in this case study about complexity costs calculation is that 16% of traded products costs have not been allocated. This is mostly due to transportation costs and depends on the number of sold pallets. Nevertheless, 84% of costs have been allocated and it seems to be a first good lever to decrease the companies' complexity costs.

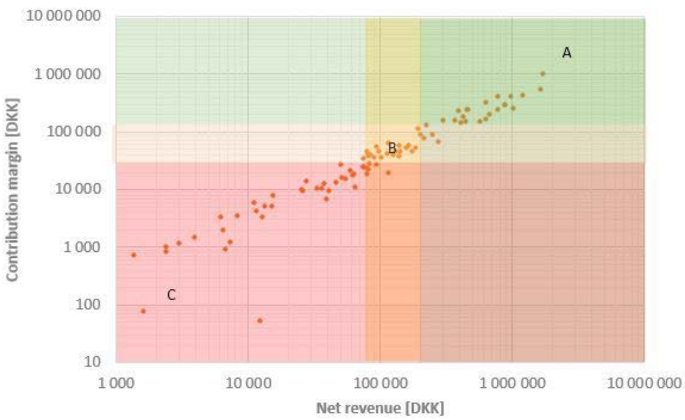
In this study case, the total amount of allocated direct and complexity costs was 128 447 470 DKK which represents 65% of products net revenues.

5.2. ABC ANALYSIS

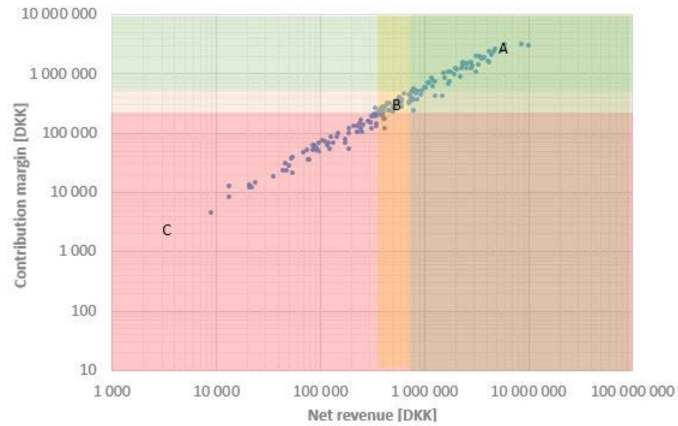
Two ABC analyses will be done; a classical ABC analysis which will be presented first and which was the one the company used and one using the complexity costs illustrated above. In order to compare the classical and the new ABC analyses, the adjusted contribution margin is calculated as followed:

$$AdjustedContributionMargin = NetRevenue - DirectProductionCost - QuantifiedComplexityCosts \tag{11}$$

Figure 4 show ABC analysis for traded and produced products, using a classical ABC calculation.



ABC analysis for traded products



ABC analysis for produced products

Figure 4. *ABC analysis (logarithmic scale is used)*

It can be seen that produced goods perform better in term of contribution margin and net revenue. it should be noticed that there are negative values of contribution margin for some products.

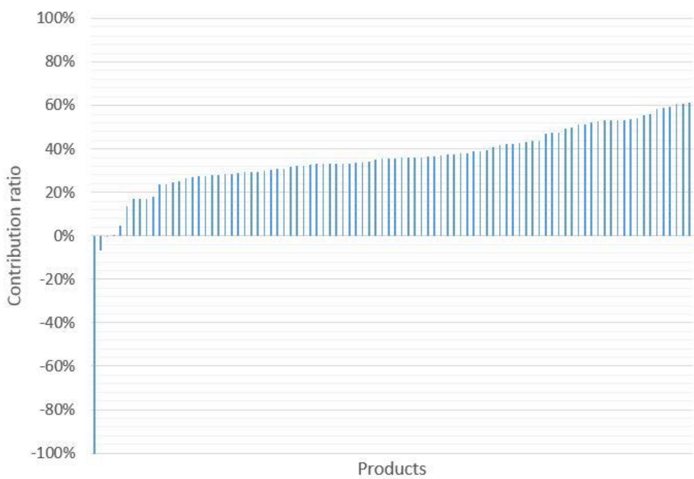
The detail of the A,B and C distribution is shown in the following table.

Table 7. *ABC category for a classical ABC analysis*

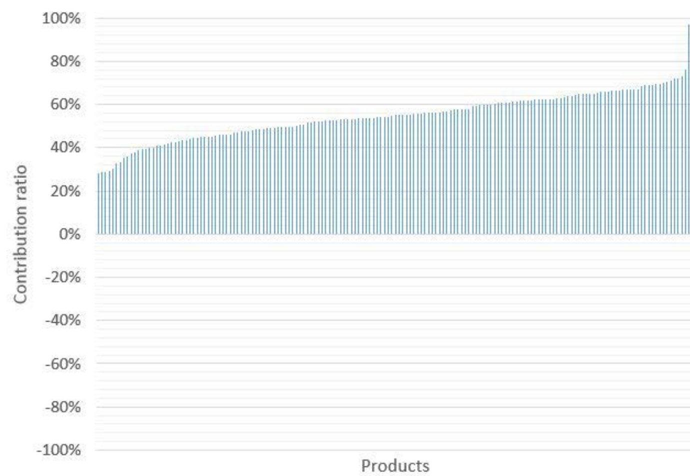
Category	Trade products	Produced products	Total
A	23	56	79
B	25	46	71
C	44	61	105
Total	92	163	255

The ContributionRatio in percentage as the relation between ContributionMargin and NetRevenue is used as an indicator for improvements. The higher the ratio for a product is, the greater the generated profit. By contrast, a small contribution ratio indicates areas for improvement (see figure 5).

$$ContributionRatio\,(\%) = \frac{ContributionMargin}{NetRevenue} \quad (12)$$



Contribution Ratio for traded products

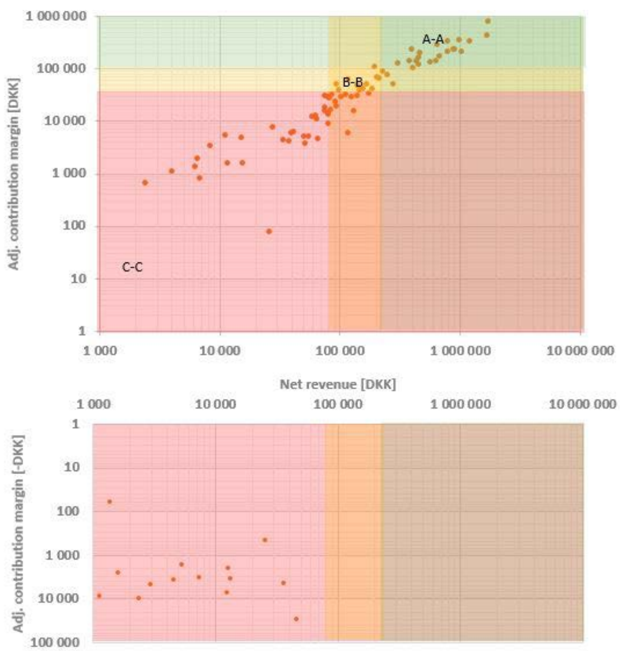


Contribution Ratio for produced products

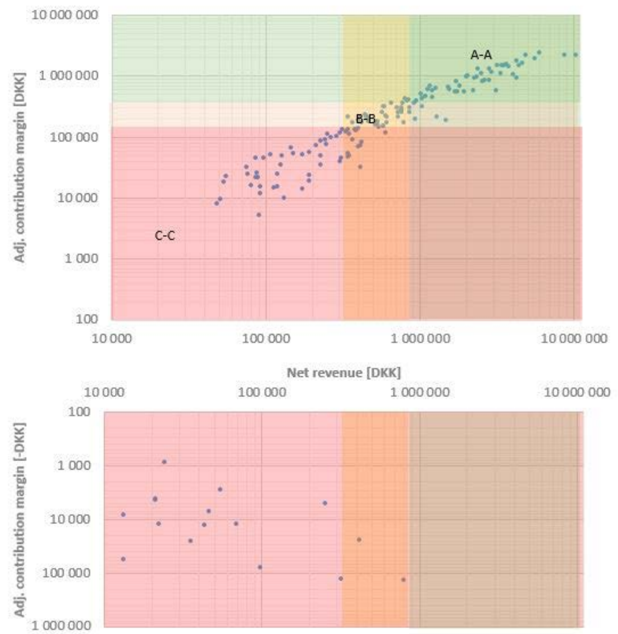
Figure 5. *Contribution ratios*

The negative contribution margin and low contribution margin of several products should be noted as well as a few products with very high contributions margins. It can be seen that the contribution ratio of produced products is on average higher than traded products; 55% for produced products and 33% for traded ones.

A new ABC analysis using the complexity costs introduced above is shown in the following.



New ABC analysis for traded products



New ABC analysis for produced products

Figure 6. *Adjusted ABC analysis (logarithmic scale is used)*

It can be seen that there is a huge gap compared to the first ABC analysis regarding contribution values. Indeed, many more products seem to generate losses.

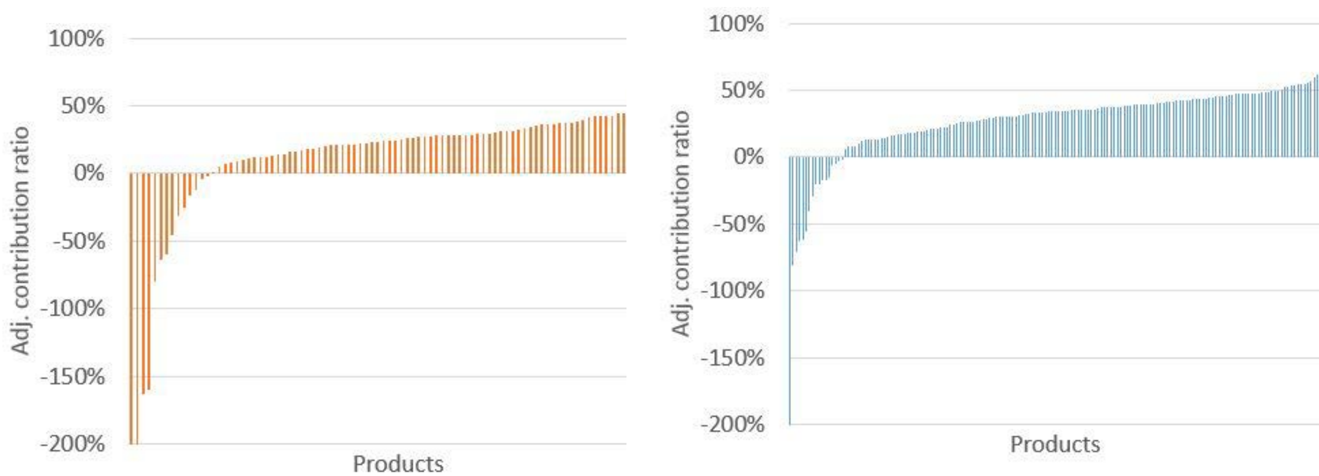
Detail of ABC classification is shown in the following table.

Table 8. *ABC category of the new ABC analysis*

Category	Trade products	Produced products	Total
A	21	47	68
B	18	38	56
C	53	78	131
Total	92	163	255

It should be noticed that the new ABC analysis leads to a tougher placement of products in categories - more products are tagged C level.

The following figure shows the contribution ratio for the new ABC analysis.



Contribution ratio for traded products

Contribution ratio for produced products

Figure 7. *Contribution ratios for the new ABC analysis*

Once again, average contribution ratio is lower for traded goods but with the use of complexity costs this value falls to 4% for traded goods and to 25% for produced goods. The ratio of allocated costs over net revenue is 65%; hence the necessary contribution ratio to cover fix costs is estimated at 35%. However, three traded products out of four and more than half of produced products have an adjusted contribution ratio lower than 35%. That is to say that these goods do not contribute to the company's profitability.

Table 9. *Detail of figures about product which have been changed of ABC category by the second ABC analysis, all prices is in DKK.*

Product	*Contribution ratio*	*First ABC category*	*Adjusted contribution ratio*	*Adjusted ABC category*

Burger bun	*56%*	*A-A*	*30%*	*B-A*
Chili sausages	*54%*	*A-A*	*41%*	*B-A*
Christmas tang	*48%*	*A-A*	*21%*	*B-A*
Texas bun	*55%*	*A-A*	*39%*	*B-A*
Buttermilk horn	*60%*	*A-A*	*30%*	*B-A*
Polka Rustic	*36%*	*A-A*	*26%*	*B-A*
Turkish bread	*61%*	*A-A*	*42%*	*B-A*
Baked sausage	*66%*	*A-B*	*47%*	*B-B*
Burger bun wholemeal	*63%*	*A-B*	*40%*	*B-B*
Focaccia 2	*63%*	*A-B*	*43%*	*B-B*
Sausages	*71%*	*A-B*	*56%*	*B-B*
Buttermilk horn, apple and caramel	*30%*	*B-B*	*-17%*	*C-B*
Focaccia, Ham and Cheese	*45%*	*B-B*	*19%*	*C-B*
Gnawing bun	*52%*	*B-B*	*26%*	*C-B*
Coarse piece	*58%*	*B-B*	*26%*	*C-B*
Grandma sausages	*58%*	*B-B*	*27%*	*C-B*
Buttermilk horn, lemon and cheese	*42%*	*B-B*	*18%*	*C-B*
Sandwich	*54%*	*B-B*	*8%*	*C-B*
Gifler	*55%*	*B-B*	*35%*	*C-B*
Sandwich chicken bacon	*49%*	*B-B*	*18%*	*C-B*
Sausage tulip	*53%*	*B-B*	*33%*	*C-B*
Brunsviger tang	*67%*	*B-B*	*36%*	*C-B*
Cinnamon stick	*54%*	*B-B*	*25%*	*C-B*
Gnawing bun, cheese	*56%*	*B-B*	*33%*	*C-B*
Baguette parisienne	*36%*	*B-B*	*12%*	*C-B*
Toffee & apple muffins	*32%*	*B-B*	*24%*	*C-B*
Mini Berliener	*36%*	*B-B*	*30%*	*C-B*
Butter croissant	*39%*	*B-B*	*27%*	*C-B*
Bread 4	*35%*	*B-B*	*21%*	*C-B*
Twist bread	*50%*	*B-B*	*36%*	*C-B*
Foccacia 4	*48%*	*B-B*	*36%*	*C-B*
Flatbread somun	*58%*	*B-B*	*37%*	*C-B*
Bread 5	*61%*	*B-C*	*39%*	*C-C*
Pulled pork horn	*55%*	*B-C*	*16%*	*C-C*
Mini cinnamon rolls	*64%*	*B-C*	*37%*	*C-C*

Chocolate cookies	*47%*	*B-C*	*41%*	*C-C*

In total 36 products changed category in the new ABC analysis, all to lower categories (see table 9).

In conclusion, the new ABC analysis gives a true picture of the complexity costs for all products and thus gives a detailed picture of which products the company should focus on to improve contribution margins.

5.3. SCENARIOS

Based on the second ABC analysis this article suggests some scenarios the case company could use to deal with complexity. Indicators such as linkage between products, substitutability and life cycle are used to evaluate the suitability of the scenarios. Linkage is when a customer buys one or more items because he bought another product in Food A/S's product portfolio. Therefore, removing one product from the product portfolio could mean lost sales for linkage products. Substitution of products means when one product in Food A/S's product portfolio share key attributes with another product and thus could be substituted. In this case study, products which share more than 80% of similarity are tagged as substitutable. Life cycle defines the position of the product in its own life cycle. In this article, three months refers to the introductory period for a product; hereafter it is assumed that the product revenue will grow.

The presented scenarios address specific removal within the ABC analysis using linkage, substitutability and life cycle position. Three scenarios are introduced: a conservative one, a medium one and a bold one. For each scenario and each ABC category a cluster of products to be removed from the portfolio is proposed. The last column in the table lists expectations; products in these clusters which should not be removed. As can be seen, in the conservative scenario also C products are targeted for removal from the product portfolio and even then not C products bought by important customers (A customers) and products in an early stage of their life cycle.

Table 10. *Proposed scenarios to address complexity costs in the case company*

Scenario	ABC category of product	Products to remove from portfolio	Exception
Conservative	C	All	Products bought by important customers and products in an early stage of their life cycle
	A-B	High substitutable products	Products bought by important customers and products in an early stage of their life cycle
Medium	C	All	Products bought by important customers
	A-B	High substitutable products	Products bought by important customers
Bold	C	All	Products bought by very important customers
	A-B	High substitutable products	Products bought by very important customers

Results of the scenarios are summarized in the next table which includes difference in revenue, cost, production time and money earned.

Table 11. *Results of different scenarios*

Scenario	ABC category	Number of products removed	Delta Net revenue	Relative net revenue change	Delta costs	Relative costs change	Delta production time	Relative production time change	Money earned
Conservative	C	15	- 199 155	- 0.1%	1 169 522	0.9%	26	0.3%	970 367
	B	3	- 234 271	- 0.1%	430 966	0.3%	19	0.2%	196 694
	A	0	0	0%	72 424	0.1%	0	0%	72 424
	All	18	- 433 427	- 0.1%	1 672 912	0.6%	45	0.3%	1 239 485
Medium	C	25	- 516 773	- 0.3%	1 486 657	1.2%	55	0.7%	969 884
	B	3	- 234 271	- 0.1%	430 966	0.3%	19	0.2%	196 694
	A	0	0	0%	72 424	0.1%	0	0%	72 424
	All	28	- 751 045	- 0.2%	1 990 047	0.7%	74	0.4%	1 239 002
Bold	C	111	- 7 134 842	- 3.6%	7 333 857	5.7%	501	6.3%	199 015
	B	9	- 828 355	- 0.4%	945 479	0.7%	67	0.8%	117 124

A	1	- 1 836 758	- 0.9%	1 909 927	1.5%	82	1%	73 169
All	121	- 9 799 955	- 1.6%	10 189 262	2.6%	650	2.7%	389 307

For each scenario the adjusted contribution margin and net revenue for traded and produced products are plotted to give an overview of the profitability of products after for each scenario (see figure 8 and 9).

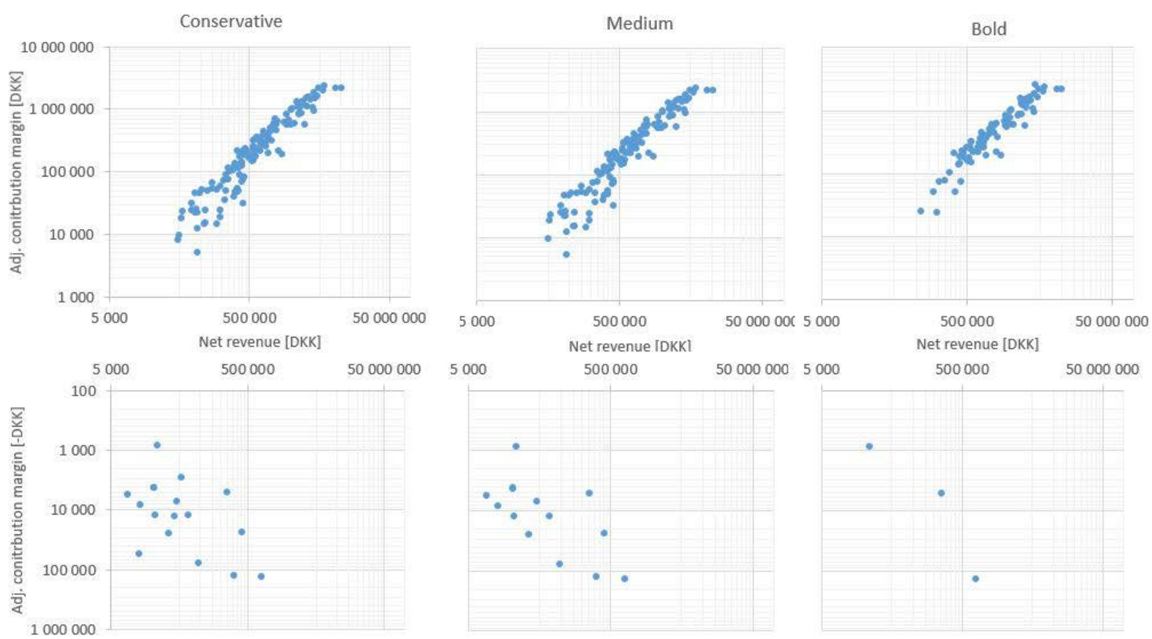


Figure 8. *Produced products ABC analysis*

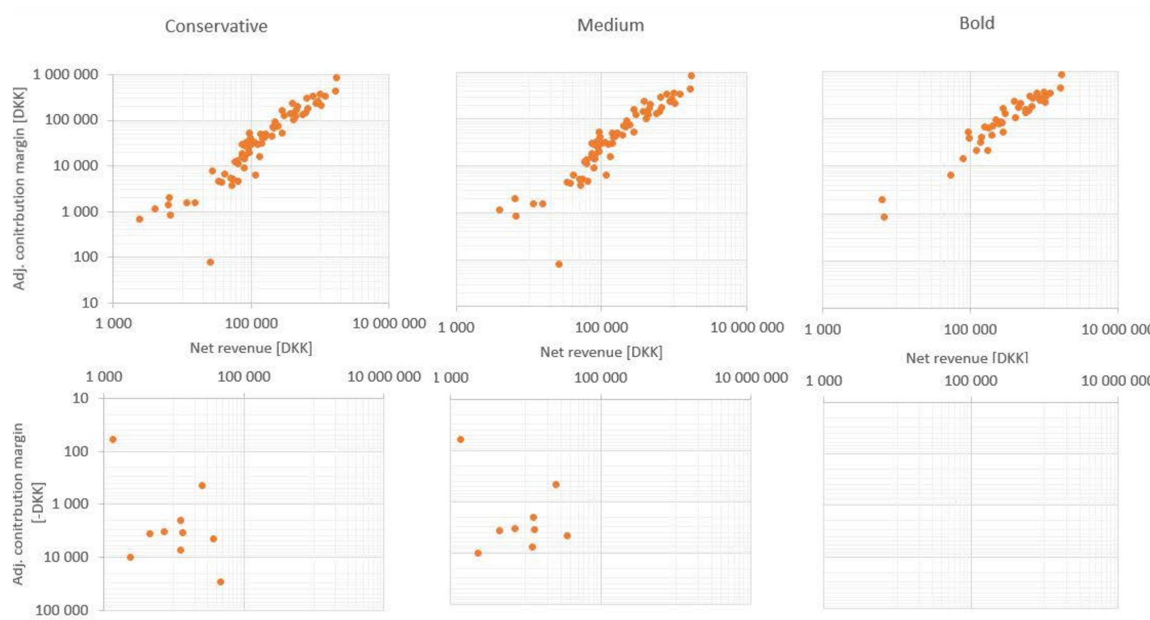


Figure 9. *Traded products ABC analysis*

As can be seen the company could save the cost in the bold scenario, but by its very nature it also carries the most risk. More specifically, the scenarios gives the following results (see figure 10 for a graphical representation):

Conservative scenario

In this scenario, 18 products are removed from the product portfolio – 15 from the C category and 3 from the B category. Variations in net revenue, costs and production hours lead to an EBIT increase of 9% for the company. Even if several products are removed, some unprofitable products still remain in the portfolio and could also have been removed. However, this scenario carries the least risk.

Medium scenario

The medium scenario leads to extending the conservative scenario with the removal of 10 additional C products. These cuts also permit a 9% increase in the case company's EBIT. This scenario is recommended as it balances risk with lower costs and substantial increase in the company's EBIT.

Bold scenario

86 additional C products, 6 additional B products and 1 additional A product are removed in addition to these in the medium scenario. However, this only leads to a 3% EBIT increase, because of the huge loss of net revenue resulting from cutting so many products from the portfolio. As this scenario cut too many working hours and doesn't increase EBIT very much, it is not recommended.

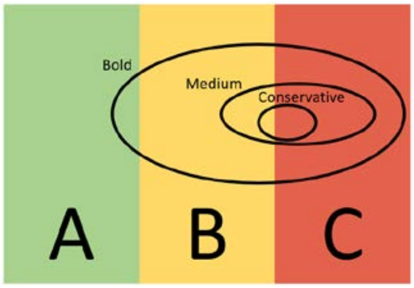


Figure 10. *Distribution of removed products for each scenario*

6. DISCUSSION

Complexity is part of a company's processes. It generates loss and have to be mastered to a necessary and sustainable level. This article introduces complexity cost formulas in order to understand the complexity and make it more transparent. Companies should aim to calculate their complexity costs at a regular interval. This interval depends on the company's own production schedule – how often it releases new products, how often customers cut in new orders etc.

In the first formula, WTC-Wasted Time Cost, focus is on the cost of wasted time due to downtimes and loss of sold products. The cost is related to the labour cost, as the production is heavy manually and therefore an expression for the production cost. With a more automatic production, another factor should be defined for the production cost. As described two causes of wasted time was used: machinery changes and human/machinery errors. For the first one, scheduling should be made in order to obtain the smoothest and most profitable production but introduced formulas shouldn't be the base of schedule improvement. Furthermore, human or machinery error, which represents the second cause, should be aimed to be zero, through training, maintenance and employee satisfaction/involvement. A more general formula for Wasted Ingredients Costs (WIC) can be introduced. as one product could contain several ingredients or semi-finished products waste and final waste cost is therefore the sum of all of this. Then if p represents all these waste possibilities, the more general formula is:

$$WIC_i = SI_i . \sum_p (IW_{ip} . CSP_{ip}) \tag{13}$$

It should be noted that the ratio $\frac{PC}{WE}$ refers to a cost of work by weight and thus use PC and WE data should be for the same laps of time.

The inventory renting and handling costs (IRCH) is calculated as a ratio of the product quantity over quantity of all products in the storehouse. Spreading values among time laps permits a more precise visibility of this cost. Indeed, if a special month – because of seasonal need or different storage emplacement for example – leads to an increase of rent of storage fees, to smooth it out would create inaccuracy of the final handling cost. In other words, the formula tries to stick to real handling costs. The inflexibility of this formula should be noted; if the price of renting differs between products then managers should choose the average price.

The calculation for inventory expiration complexity costs were based on the case study. Therefore, this calculation is likely different for another company and they may well handle inventory expiration costs in another way. However, the food industry is a particular business sector and it is likely that a large amount of companies in this industry face similar complexity costs as the characteristics for this industry are similar and there has been an increased focus in this industry on reducing food waste. It should be noted that this complexity cost equation doesn't consider pallet losses, which can distort calculations.

To conduct a second ABC analysis using complexity costs calculations will require more work. A prerequisite for calculating complexity costs is a detailed level of data that the company should be able to provide. However, by making a classical ABC analysis to understand the current portfolio situation and to make the second one to point out complexity costs aids the company in reducing complexity costs. Of course, these analyses cannot stand-alone; an ABC analysis of customers, market analysis etc. should support them.

The food industry faces a series of factors – customers demanding huge variability of products, variability in quantities, low prices for products, seasonality, quality, short expiration date – which leads to this industry facing high complexity costs but has a need to keep costs low as customer loyalty in the food industry is in general quite low. So what is the appropriate behaviour to satisfy customers who always want more and more varieties of their favourite products? In a lot of industries this issue can be addressed with mass customization or modularization: Customers could order their product and factories would produce it using modules. Obviously this is not possible in the food industry. For some products – not entirely cooked products such as frozen dough, half cooked bread, etc. – it would be possible to explain how to customize the cooking with additional ingredients. For example, bread dough could be baked alone, with seeds, with chocolate or with seeds and chocolate. In this way companies are able to reduce costs of production while still being able to propose several different products to their customers. Of course it doesn't work for fully baked products because if customer buys them it is in part for their attribute of "ready to eat". In short, this industry, perhaps more than any other, need to carefully balance what complexity is needed for customers to want to buy the products while getting rid of as many complexity costs as possible to keep costs down.

7. IMPLICATIONS

This paper applies complexity cost calculations to a case company in the food industry. An area not well researched before. The proposed complexity costs calculations have proved significant improvements to the case company. The calculations consider the key challenges the industry face; for example efficiency, time and quality. Furthermore, costs of ingredients, expiration date and storage – the latter two often with large costs for this industry – were detailed. This paper aims to merge all material costs in the same basket, ones during the process and ones concerning finished products. The novelty of this article is to propose complexity cost formulas that can be easily used by the food industry – an industry with a majority of SME's and therefore limited resources to invest.

In practice this paper suggests the following complexity cost framework, consisting of 7 steps which make up an iterative process, e.g. after complexation of step 7 step 1 will be restarted after a certain time period:

1. Choice of products cluster and data gathering. In the food industry there are many SME’s who might not be able to afford a full complexity cost analysis of their complete product portfolio. Therefore, the first choice is therefore what part of the portfolio to analyse;
2. Data gathering. Data gathering is the cornerstone of complexity cost calculations. Indeed, each result, calculation or proposal bases on the reliability of data. Therefore, detailed and reliable cost data has to be gathered or – if it doesn’t exist in the company yet – it has to be created;
3. Classical ABC analysis. Within the chosen cluster of products, make a first ABC analysis in order to understand how the company currently classifies products. Most companies will already have done this so the cost of this step should be minimal;
4. Complexity costs calculation. Calculate and analyse the complexity cost using the presented formulas. It should lead to a first idea of improvement areas for the company;
5. Second ABC analysis. Make a new ABC analysis using the complexity cost calculations;
6. Scenarios creation and selection. As done in the case study, it is highly recommended to make several scenarios of portfolio cutting or improvement to see how it can affect the company’s results and processes. Furthermore, how these decisions fit in with the corporate strategy is important. For example, if production time frees up can it then be filled with other products? Can new products be introduced? How does it affect production - is there a need for new machines, maintenance, hiring or firing of employees? All these elements have to be considered to ensure all pros and cons of the decision has been evaluated and prepared for;
7. Implement the selected scenario;

It is recommended to run the steps on a periodic basis to ensure complexity costs are continuously kept under control.

8. CONCLUSION

Complexity is a growing issue in the food industry but not well-researched. This paper contributes with empirical research within operations management. The research question was, “Which complexity factors can be quantified in the food industry and how can they be used in economic calculations?” This was answered through a case study at an SME food producer in Denmark – a typical example from this industry where the majority of players on the market are SMEs. The result of this paper is in three steps. First, it identifies a set of complexity factors arranged and calculated in the following key complexity cost formulas:

- Wasted Time Costs (WTC)
- Wasted Time Ratio (WTR)
- Time Wasted Cost (TWC)
- Effective Time Ratio (ETC)
- Wasted Ingredients Costs (WIC)
- Wasted Products Costs (WPC)
- Inventory renting and handling costs (IRCH)
- Expiration costs (EC)

In the analysis, the storage and expiration date costs are among the largest complexity costs for this industry. Second, the paper shows how these calculations can be used to carry out a new ABC analysis and use this to create improvement scenarios for the case company. Finally, a guide to managers in the food industry describes a complexity costs framework.

Further studies will focus on detailing the complexity cost analysis and further developing a complexity costs framework for this industry, including using the framework with other companies in the industry.

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