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The degree of inventory centralization for food manufacturers

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Abstract For food manufacturers, limited shelf-lives and 'freshness' requirements increase inventory holding costs. Accuracy in choosing the most advantageous degree of inventory centralization (MADIC) is therefore central for competitiveness. While extant research contains several industry-generic factors that influence centralization decisions, influencing factors for food manufacturers, in particular, is under-explored. This paper identifies the factors that influence the MADIC for food manufacturers and develops a method that integrates all factors for MADIC-determination. The study examines a single case facilitating deep-dives into unknown areas. Results show nine factors of which three are specific to food manufacturing. Furthermore, the paper details how practitioners can determine a MADIC-score on a 1-100 scale for their particular operations. While food manufacturing inventory centralization literature is scarce, this paper contributes to a holistic study of multiple relevant factors and a method that integrates all factors into one result.

Keywords Centralization, decentralization, food manufacturing, inventory management, case study research, multicriteria decisions

1 Introduction

Inventory management plays an important role in modern supply chains and enables manufacturers to achieve competitive advantage through higher service levels at lower costs [1,2]. Inventory is an essential resource for day-to-day operations and acts as a buffer against demand and supply uncertainties. However, inventory is costly. Wilson [3] estimates that inventory holding costs account for approximately one third of total logistics costs.

After the 2008 financial crisis, businesses have faced the challenge of reducing costs while keeping service intact. Minimizing inventory investment has therefore received increased attention [4]. Selecting an appropriate inventory strategy can reduce costs as well as time-distance to customers and thereby service levels [5,6].

Food supply chains are increasingly global, leaving firms and their efforts to ensure product availability vulnerable to political and border issues as well as environmental issues [7,8]. Holding inventory with close customer proximity minimises these risks [2]. On the other hand, agility scholars would claim that inventory reduces flexibility and the ability to respond demand changes [9]. Hence, inventory is strategically relevant both as a matter of employed capital, but also for ensuring customer service and reducing [6].

The food industry is one of the EU's largest manufacturing segments. The industry earns revenues of EUR 940 billion yearly representing 13,5% of the manufacturing sector [10]. The food industry has changed rapidly in the past decade, moving towards increasingly complex supply chains [11]. Short shelf lives, unpredictable demand and supply, stringent food safety regulations, and sustainability requirements [12] requires complex management of inventories.

One managerial decision concerning inventory is whether to centralize or decentralize inventories. Centralizing inventories reduces costs and overall inventory [13–15], but increases customer proximity and transportation costs, and possibly reduces service levels [13,16]. Moreover, demand and supply uncertainty affects the decision for *risk pooling* and *risk diversification effects* [17–19].

While centralization vs. decentralization of inventories has been extensively investigated from diverse perspectives [1,13–15,17–25], food manufacturing literature has given the subject scarce attention.

The general inventory centralization literature examines individual factors' impact on performance using mathematical models and simulations. Missing in literature is a holistic, multidisciplinary approach that integrates all (or at least the most) relevant factors to determine a firm's most advantageous degree of inventory centralization (MADIC). Moreover, extant research includes only few actual case studies that illustrate the potential benefits MADIC in real supply chains [26–29].

The purpose of this study is to develop this missing holistic approach for application in the food manufacturing industry. The approach will integrate the factors influencing the centralization decision specifically for food manufacturers to determine MADIC for any given food manufacturer. To develop the approach, the study answers two research questions (RQs):

- *RQ1: Which factors influence the inventory centralization decision of food manufacturers?*
- *RQ2: How can the MADIC be determined with an approach that integrates all factors identified from the first RQ?*

The study focuses solely on finished goods inventory, which represents the largest inventory investment for food manufacturers.

The paper is structured as follows. Section 2 reviews literature to identify MADIC-influencing factors described in extant literature. Section 3 presents the study's research design. Section 4 analyses the

study's dataset, and section 5 discusses results. Section 6 presents implications for theory and practice and section 7 provides conclusions, key managerial challenges and suggestions for further research.

2 Literature review

The literature review first describes the unique nature of food manufacturing vis-à-vis manufacturing of durable goods (e.g. electronic and mechanical products). Second, the section develops a typology with the two extreme inventory configurations, i.e. a 100% centralized inventory configuration vs. a 100% decentralized configuration. Third, the section identifies factors that influence MADIC (general factors followed by food manufacturing specific factors).

2.1 The unique nature of food manufacturing

Food manufacturing has a unique nature. Product shelf lives vary substantially and are limited compared to manufacturing of metal or plastic products. The quality of food products deteriorates at much higher rates than in other industries. The industry needs special and expensive storage facilities, often large freezing capacities.

Suppliers of food manufacturers often have seasonal harvests (e.g. grains and fruits), while consumption is year-round. Prices are unstable and large percentages of products are sold at discount. For some products, security of supply is low, which leads to purchases of large quantities with storage needs. There are large differences in shelf-life per Stock Keeping Unit (SKU) leading to heterogenic inventory policies. FIFO rather than the convenient LIFO is widely applied leading to higher rates of reshuffling of cubes and pallet positions.

The industry experiences high levels of uncertainty in yield (a fish is not the same size every time or has the same fat vs. protein ratio). Uneven yields result in uneven material flow, which makes it difficult to apply classic lot sizing models.

Customers increasingly expect fresh products at the expense of frozen and canned foods. Customer requirements are often changing subject to fads and longer trends, and are becoming more fragmented. New segments are growing in size (e.g. organic products, vegan products, local products etc.).

Much research seeks to model and solve the food manufacturing lot sizing problems. However, a review by Yano and Lee [30] found that models lack real world fitness.

2.2 The two extremes: A centralized and a decentralized inventory configuration

This section describes the two extreme inventory configurations (i.e. 100% centralized configuration and a 0% centralized configuration).

Following Wanke and Saliby [31], this study defines a centralized inventory configuration as '*physical consolidation of stocks at a limited number of locations (often a single facility) from which all demand is satisfied'*. In this study, inventory centralization also refers to the organization, operations, and management of the firm's inventory and inventory processes. A decentralized inventory configuration is charachterized by '*separate inventory locations from which each market is independently served'*. Management and operations are local. These two configurations are extremes on a scale that represents the degree of inventory centralization. The two extremes are a 0% centralized configuration to a 100% centralized configuration.

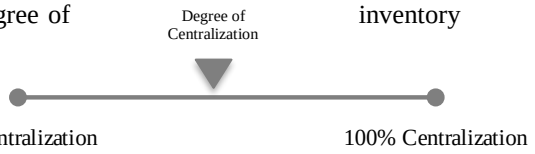

Fig. 1 Conceptual scale of the degree of inventory centralization. Adapted from Hansen et al. (2017)

2.3 Identification of factors that influence MADIC

This section first identifies factors that generally influence MADIC and second factors that apply specifically in food manufacturing.

2.3.1 Factors that influence MADIC generally

The section first lists the advantages of a centralized configuration and second the advantages of a decentralized configuration.

2.3.1.1 Arguments for centralisation

According to Oskarsson, Ekdahl, and Aronsson [32] the two advantages of a centralized configuration are cost reductions and increased service. The next paragraphs detail these advantages.

Several studies show that inventory costs decrease because the control and management of the material flows are easier with a centralized configuration [1,13,15,25]. A centralized configuration requires less inventory to serve a set of markets as the demand variance in each source is counterbalanced. This concept has been named as *risk pooling effect* [17, 23].

The *square root law* introduced by [33] states that the safety stock in *N* parallel warehouses is proportional to the square root of *N*. This model has been widely used in the design of distribution networks [15,34–36]. However, due to its simplistic assumptions [37] later research has extended the original model [23,38–41].

Zinn, Levy, and Bowersox [14] introduced a new measure, called the *portfolio effect*, for evaluating the effect of inventory centralization on aggregate inventory when demands are correlated. The *portfolio effect* model calculates a reduction in aggregate safety stock made enabled by inventory centralization [42]. Various

studies have extended and modified this measure and its applications [43,44]. The required safety stock is lowered [14] as pooling of the demand results in lower aggregate demand uncertainty.

Centralization ties up less capital, reduces warehousing employees and learning costs [1] and reduces fixed warehousing costs [15]. Abrahamsson [1] shows that centralizing inventories does not necessarily lead to increased delivery time even though the average distance to customers increases. This is the case when the centralized inventory keeps a complete assortment and operates a smooth flow of deliveries, and thereby less express freights, are factors present [45]. Teo, Ou, and Goh [20] show that centralization generally leads to reduced facility investment costs, promotes benefits from increased economies of scale in purchasing and transportation operations, and reduces inventory duplications. Centralization increases inventory turnover and the probability of deterioration during storage.

Concerning service levels, centralization promotes better precision in lead-times by keeping a wider range of products that is unviable in smaller warehouse. Moreover, as centralization reduces the number of communication paths and personal relations, the configuration provides faster and more precise delivery information to customers [1]. Centralized inventory enables more effective quality control and stock visibility [20].

2.3.1.2 Arguments for decentralization

When demand at different locations is correlated, the reduction in safety stock due to centralization may no longer apply and the total safety stock may even increase significantly [37]. Other advantages of a decentralized configuration in delivery times and costs [25], increased proximity to customers and customer service [13], and thus smaller expected costs of lost sales [1].

Zinn, Levy, and Bowersox [14] discuss that adding stock points can improve customer service without the habitual additions in aggregate safety stock as argued by Mahmoud [24] and Croxton and Zinn [15]. The controlling capabilities can be another factor promoting decentralization of inventory, as it has been argued that top executives do no possess the same ability to make operational decisions as local management at a decentralized network [46]. Moreover, Axsäer [47] states that in practice decentralization of control is generally more attractive because a centralized system requires strategic planning and alignment throughout the chain [48]. Therefore, a centralized inventory configuration requires higher levels of controlling capabilities, whilst a decentralized configuration only requires local controlling capabilities.

The study conducted by Wanke and Zinn [21] show that firms with high inventory turnover are more likely to pursue a decentralized warehousing structure. Jonsson and Mattsson [22] argue that the need for aggregation may decrease as the range of product variations increases. Corbett and Rajaram [18] explore the *risk diversification effect* (also known as *supply risk mitigation*) and show that under supply uncertainty, decentralization results in an approximately equal mean cost but less cost variability than centralization does. This occurs because disruption in a centralized system affects every retailer and causes more drastic cost variability than in a decentralized system. Similar results are obtained in Schmitt et al. [19], which provides evidence that decentralization is usually optimal for risk-averse supply chains subject to both supply disruptions and demand uncertainty.

Teo, Ou, and Goh [20] explores the effect of demand distribution on facility investment and inventory costs and shows that for general stochastic demand processes, the total facility investment and inventory costs of a centralized system can be infinitely worse off than that of a decentralized system.

Extant research has attempted easy to understand explanations of the relationship between the number of warehouses and inventory levels, which has resulted in various mathematical models for evaluating network design decisions [49]. However, current supply chains face high service level requirements, lead-times volatility, and replenishment frequency variance, which problematizes the effectiveness of simple rules for accurate inventory predictions.

2.3.2 Factors that influence MADIC particularly for food manufacturers

Although increasing complexity and competitive rivalry food supply chains [11] has led to increasing levels of research into inventory management in food manufacturing, the topic of inventory centralization has received scarce attention. Instead, other key areas are examined, e.g. supply chain performance, lean and agile strategies, supply chain flexibility, traceability or sustainability. When evaluating MADIC, a particular set of food supply chain characteristics are worth examining.

The food industry is characterized by high frequencies of new product introductions [50–52], which increases consumer choices, on the one hand, and demand uncertainty, on the other. In addition, supply of materials from agriculture and fishing industries are unstable due to natural factors [12]. Examples are volcanic eruptions, droughts, excessive rain, etc. Thus, *demand and supply risk patterns* from both consumer expectations and natural factors influence the inventory centralization decision for food manufacturers.

Food supply chains have become global, and the number of markets served has consequently increased [51]. Because products ranges in food manufacturing are high combined with global supply and market demand leads to increased product portfolio complexity across demand markets. The differences in product portfolios across markets impacts a food manufacturers ability avoid stock duplication in a centralized inventory configuration. Therefore, *product variation* is a relevant

factor to consider when analysing centralization vs. decentralization of inventories.

When food manufacturers introduce new products, these new products often take the place of an older product that the manufacturer phase out. This product substitution process requires efficient stock rotation to avoid leftovers. If the *product substitution frequency* is high, a centralized inventory configuration with higher inventory rotation minimizes the risk of product obsolescence and spoilage.

Akkerman, Van Der Meer, and Van Donk [53] and Liang [54] emphasize the importance of warehouse efficiency in food manufacturing food companies, being the major problem affecting efficiency in this industry.

Table 1 Summary of factors that influence MADIC for food manufacturers

No.	Factor	Description	Centralization	Key references	Decentralization	Key references
F1	Inventory levels	Amount of goods in stock at the warehouses	Aggregate safety stock level (-) Cycle stock level (-) Duplication of inventories (-) Range of products to be stored (+) Inventory turnover (+)	[1,13] [15,20,25]	N/A	N/A
F2	Warehousing costs	Warehousing operations efficiency and costs involved in running a warehouse	Warehousing staff (-) Warehousing locations (-) Warehousing fix costs (-) Facility investment costs (-)	[15,20]	N/A	N/A
F3	Transportation costs	Transportation operations efficiency and costs involved in moving goods from production site to warehouses and to warehouses to customers	Economies of scale (+) Complexity of distribution network (-)	[1,20]	Distance to customer (-) Transportation costs to customer (-)	[25]
F4	Service levels	Performance of inventory strategy regarding service to customers	Precision in lead-times to customer (+) Speed and precision of delivery information to customer (+)	[1,20]	Lead-time to customer (-) Proximity to customer (+) Local exposure (+) Customer service (+) Expected cost of lost sales (-)	[1,13,14,25]
F5	Control capabilities	Inventory control systems and management competences	Visibility of stocks (+) Control of inventory flow (+) Quality control (+) Complexity of communication paths and relations network (-) Higher level of controlling capabilities are needed. Strategic planning and alignment is needed (~)	[15,20,25,48]	Ease of local control (+) Limited local controlling capabilities are needed. Local managers can be more suited for taking operational decisions that top managers (~)	[46,48]
F6	Demand and supply risk patterns	The supply and demand pattern imposed to the firm	Aggregate demand uncertainty (-) Demand risk mitigation (+)	[17,23]	Global impact given supply disruption (-) Supply risk mitigation (+)	[18]
F7	Product variation	Number of product variants shared across markets vs. market specific products	The fact that different markets share the same product is generally required to benefit from centralization (~)	[22,55]	If markets are product-specific, centralization of inventories might not be advantageous (~)	N/A
F8	Product substitution	Frequency of new product launches substituting old products	If frequency of launches is high, the inventory of old products being substituted needs to be consumed fast. Centralization strategies promote high inventory rotation (~)	[20,50]	If frequency of product substitution is low, decentralization might not be advantageous as inventory turnover is not a key driver (~)	N/A
F9	Product shelf-life	Length of time that a product can be stored before being sold	Probability of deterioration during storage (-) Limited shelf-life products require effective inventory rotation, which is enhanced by centralization strategies (~)	[20,54,56]	If shelf-life is not critical, decentralization might not be advantageous as inventory turnover is not a key driver (~)	N/A

Warehouse efficiency can be strengthened in centralized configurations.

Food products have limited shelf-life, thus effective stock rotation and adequate stock levels are essential to avoid spoilage [54,56]. *Product shelf-life*, which is linked to *inventory levels*, suggests that increased inventory rotation easier achieved in centralized configurations preferable for products with short shelf-lives.

Table 1 summarizes results and lists 9 factors that influence the MADIC for food manufacturers.

3. Research methodology

The results from the literature review constitutes a simple theoretical framework for determining MADIC for individual food manufacturers. To validate and refine the proposed theoretical framework, known as *theory building*, as well as to examine the practical implications of the framework's implementation [57,58], the paper conducts an in-depth case study with five overall objectives. Objectives one and two concern validation and refinement of the proposed theoretical framework, while objectives three to five concern the practical implications of the framework's implementation

(1) To assess the relevance of the set of MADIC-influencing factors in the theoretical framework
(2) To identify potential new factors that extant literature has yet to explore
(3) To assess the case firm's current degree of inventory centralization
(4) For the case firm, to identify the degree of inventory centralization that the influencing factors point to as most advantageous (i.e. MADIC)

(5) To examine which specific actions can close the gap between the current and the desired degree of centralization.

Objectives three to five indicate that the study applies case research. The study addresses all five objectives through an in-depth study of a food manufacturer. The firm, which for confidentiality reasons is labelled NordicFood, is currently facing the choice between centralizing and decentralizing the firm's warehouse structure. NordicFood operates within the entire Nordic region consisting of Denmark, Norway, Sweden and Finland. The scope of this study is limited to NordicFood's finished goods inventory.

The study examines a single case, which facilitates deep-dives into unknown knowledge, because identification of factors that are idiosyncratic to the food manufacturing industry, requires inquiry into areas and subjects that are unknown *a priori*. Because of the explorative nature of the research objectives, the study needs in-depth qualitative and quantitative data and takes the context of the firm's inventory in account. Therefore, the study applies the case study [59,60].

Yin [59] defines case research as an iterative process that empirically analyses a contemporary phenomenon within its real-life context. The method allows for validating and improving theory by means of combining existing theories with practical insights. Moreover, as outlined by Vissak [60], case studies allow studying phenomena within contexts and in their full complexity.

Although case research fits well with the study's research objectives, the method does have drawbacks. Case research is more time-consuming than e.g. surveys, and the method has been criticized for lacking rigor and a limited ability to draw generalizations, especially when the sample size is small [60]. To overcome this limitation, the case analysis will be evaluated on the four criteria put forth by Hilmola, Hejazi, and Ojala [61] for a successful descriptive case study: *relevant to practitioners*, *theoretical connections*, *usability in practice* and *theoretical novelty value*.

The specific method applied is the *descriptive case study*. Descriptive case studies are often used when there is a ready model and the aim is to study particular aspects of a topic [62]. Specifically, the *descriptive deductive method* was chosen for the case analysis as it draws on theory and logical findings from literature to answer the presented research questions [61]. The case study has a single unit of analysis, which is the finished goods inventory of NordicFood. The case firm is representative for the food industry in the Nordic region.

3.1 Data collection

The study collected data from multiple data sources: Internal written documents, informal conversations and interviews with key informants, observations and shadowing of employees, and quantitative data reports. One researcher was physically located for five months at the firm's headquarters, which provided access to multiple informants and other data sources. The physical presence for a lengthy time period enabled a better understanding of the firm's supply chain.

The study applies both quantitative and qualitative data, which provides the basis for meeting the five research objectives stated earlier in this section. The two data types each have their own strengths and weaknesses, but in interaction they complement each other [63]. The sources and the purpose of the data gathered are summarized in Table 2.

Table 2 Quantitative and qualitative data sources

Type of Data	Purpose	Data source
Qualitative data	Provides foundation for in-depth investigation of the research questions and opens up for a more nuanced view of the problem. Provides detailed information in areas of interest by key contacts.	Open-ended and semi-structured interviews
Quantitative data	Quantify current supply chain configuration through different measures calculated and quantify relevant factors.	Historical data from 2016. The horizon is one year in order to incorporate any potential seasonality. Retrieved from reports from ERP system and SAP transactions.

3.1.1 Data validity

The study conducted 12 interviews with managers and employees in different positions of the case firm. The interviews were designed as semi-structured and open-ended allowing free associations. Interviews were recorded, transcribed and analysed using the condensation principle [64] to extract the relevant information. To ensure validity of interview data, multiple sources of evidence were used for triangulation and for identifying converging themes and lines of inquiry [58]. To ensure construct validity, the study established a clear chain of evidence, adopted different angles from which to examine the phenomenon, and had key informants review case study reports [59].

To minimize subjective interpretations and bias, the study summarized key points from interview. These summaries were subsequently examined and checked by informants. Misunderstandings were corrected and clarified, thus ensuring rigour and interview transparency. Quantitative data was also shared with informants to verify its correctness.

3.2 Method of analysis

The purpose of the analysis is to assess the match between NordicFood's current degree of inventory centralization and the MADIC. The analysis, which is inspired by Cross [65] and Hansen et al. [66] consists of

two stages depicted in Figure 2 as the two grey horizontal bars.

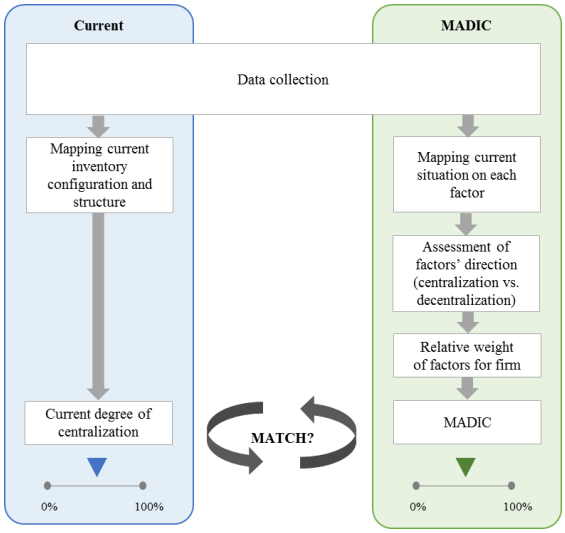

Fig. 2 The case study's analytical structure

The study assesses the firm's current degree of inventory centralization by studying the firm's current inventory configuration, including and structure, management principles, required service levels etc. To identify MADIC, the study first examines the situation on each factor from the theoretical framework developed in the paper's literature review. Second, the study examines the direction of each factor, i.e. whether the factor points towards centralization or decentralization. Third, the study calculates the MADIC taking into account the relative weight of each factor for the firm. The study calculates MADIC using expression (1). The result enables placing the firm's MADIC on the 1-100 scale in Figure 1.

$$MADIC\ [\%] = \frac{(\sum relative\ weight \cdot factor\ direction) + 1}{2} \cdot 100 \quad (1)$$

Expression (1) multiplies the relative weight of each factor with the factor's direction (i.e. -1 if pointing towards decentralization; 1 if pointing towards centralization; 0 if ambiguous). The expression includes normalization, so results range between 0% and 100%.

4. Findings

This section presents the case study findings. First, the section presents the case firm's current inventory configuration. Second, the section presents the firm's stance on each factor in the theoretical framework. Third, the section presents the firm's current degree of inventory centralization and MADIC. Both results are placed on the 1-100 scale in Figure 1. The section concludes by suggesting actions and initiatives that will close the gap between the firm's current degree of inventory centralization and MADIC.

4.1 The case firm's current inventory configuration

NordicFood distributes finished food products in the Nordic region. The firm's currently serves its Nordic markets from four distribution centres (DC). One DC is located in Denmark (DK1), one in Sweden (SE1), and two in Finland (FI1 and FI2). The firm operates its three markets as single business units. DK1 serves Danish customers, SE1 serves Swedish and Norwegian customers, and FI1 and FI2 warehouses serve Finish customers.

The four warehouses are managed as individual accounts, but the replenishment policy is common. The firm uses 19 different logistics providers to distribute the products. These logistics providers are managed separately, country by country. Lateral transhipments between warehouses are occasionally done to balance stock due to unexpected changes in demand. The firm forecasts demand independently and not share advertising, promotional activities, etc. The firm and its suppliers share data through an EDI system, where data such as production planning, forecast and inventory levels are visible for all NordicFood warehouse managers and all suppliers.

4.2 Determining Current centralization degree & MADIC for the case firm

Table 3 shows the direction of each factor from the theoretical framework developed in the paper's literature review. Based on the interviews and feedback from the NordicFood, the table 3 shows the current direction towards centralization and MADIC direction based on the future strategy. Table 3 shows that all but one factor suggest that MADIC is close to a completely centralized inventory configuration. The following section in the analysis leads to a more precisely calculated current and MADIC score for the case firm.

Table 3 MADIC determination for the case firm

No.	Factor	Current direction	Case analysis based on the future strategy	MADIC direction
F1	Inventory levels	Centralization (1)	The firm wishes to reduce inventory levels, thus the factor points towards centralization.	Centralization (1)
F2	Warehousing costs	Decentralization (-1)	The firm wishes to improve operations efficiency, flexibility and agility, which points towards centralization.	Centralization (1)
F3	Transportation costs	Decentralization (-1)	The firm wishes to reduce transport costs and complexity in the distribution network, which points towards centralization.	Centralization (1)
F4	Service level	Decentralization (-1)	The firm wishes to maintain customer service and lead-times at current levels, but want to improve precision and speed of delivery information to customer. The factor's direction is ambiguous	Centralization / Decentralization (0)

F5	Control capabilities	Centralization (1)	The firm's objective is high levels of controlling capabilities. For example, replenishment planning by a centralized team, visibility of stock, and high levels of control of inventory. The factor points towards centralization.	Centralization (1)
F6	Demand and supply risk patterns	Centralization (1)	The risk pattern imposed to the firm's finished goods inventory is defined by higher demand uncertainty than supply uncertainty because vendors upstream in the supply chain are internal to the firm and collaboration is high. Demand risk mitigation is prioritized, pointing towards centralization.	Centralization (1)
F7	Product variation	Decentralization (-1)	Current product portfolios are highly misaligned between markets, pointing towards decentralization. However, the firm wishes to reduce product variants and align markets, which points towards centralization.	Centralization (1)
F8	Product substitution	Centralization (1)	Product launch frequency is high and the firm's interest on keeping a high inventory turnover to avoid product leftovers is high, which points towards centralization.	Centralization (1)
F9	Product shelf-life	Centralization (1)	Product shelf-life is a concern now and will be even more important in the future. Frequent rotation of inventory is critical to avoid spoilage, pointing towards centralization.	Centralization (1)

Table 4 Quantitative analysis of current centralization and MADIC

	Average weight (MADIC)
F1	4,58
F2	3,83
F3	4,33
F4	4,83
F5	4
F6	4
F7	4,33
F8	3,20
F9	3,67

	F1	F2	F3	F4	F5	F6	F7	F8	F9
F1		1	1	0	1	1	1	1	1
F2	0		0	0	0	0	0	1	1
F3	0	1		0	1	1	0,5	1	1
F4	1	1	1		1	1	1	1	1
F5	0	1	0	0		0,5	0	1	1
F6	0	1	0	0	0,5		0	1	1
F7	0	1	0,5	0	1	1		1	1
F8	0	0	0	0	0	0	0		0
F9	0	0	0	0	0	0	0	1	

Absolute weight (MADIC)	Relative weight (MADIC)	Centralization or decentralization (MADIC)	Centralization or decentralization (Current)	Relative weight (Current)
7	19%	1	1	21%
2	6%	1	-1	7%
5,5	15%	1	-1	11%
8	22%	0	-1	21%
3,5	10%	1	1	3%
3,5	10%	1	1	17%
5,5	15%	1	1	0%
0	0%	1	1	14%
1	3%	1	1	21%

Table 4 shows the results from this procedure.

4.3 Quantitative case analysis of the case firm's current and MADIC score

The objective of this quantitative analysis is to calculate the MADIC as a percentage that can be placed on the 0-100% scale presented in the paper's literature review and compared to the firm's current degree of inventory centralization. For this purpose, the study applies a three-step procedure:

(1) Informants within the firm weighted the factors using 5-point scale

(2) The weights obtained across respondents were averaged and transformed into absolute factor weights through pairwise factor comparisons. For example, if the F1 has higher average weight than F2 then it will be given a value 1 and 0 otherwise. In case the average weights are the same the value of 0.5 is given. The absolute weight is calculated by summation of the factors for each factor.

(3) The absolute weights were transformed into relative weights by calculating the percentage value for each absolute weight

Using expression (1), the relative weights and factor directions, the MADIC for NordicFood is 89%, whereas, the current score is 54%.

Figure 3 displays the results visualized on the scale of degree of inventory centralization defined in section 2.2.

Figure 3 shows a significant gap between the firm's current position and MADIC. The MADIC calculation strongly suggests reconfiguring the firm's current finished goods inventory towards a more centralized configuration.

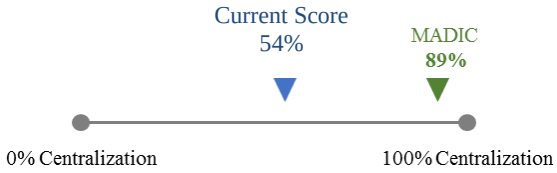

Fig. 3 Analysis results visualized for the current degree of inventory centralization and MADIC

5. Discussion and suggestions for moving towards MADIC

As discussed in previous sections, as per the interviews, NordicFood wants to move towards centralization (section 4.2 and table 3). Whereas, the current analysis shows 40% to 60% centralization (section 4.1), however, there exist MADIC analysis shows that this can be improved up till 89% (section 4.2).

To close the gap between the firm's current degree of inventory centralization and MADIC, the study proposes a number of initiatives for implementation based on the analysis of the current situation with the company's desired state.

As per Table 3, the company wants to reduce the transportation cost, whereas, as per section 4.1, it is using 19 different freight providers in the supply chain. Reducing the number of freight providers can increase the centralization degree. Moreover, the NordicFood wants to have high customer service level and visibility of the stock (Table 3), hence information sharing with customers with potential out-of-stocks and delivery time can help in achieving this goal and will also lead in increasing centralization. Additionally, SKU rationalization to reduce portfolio complexity will help controlling product variation (Table 3) and increase the centralization. Lastly, by physical centralization of distribution network will also help in increasing the centralization degree. Table 5 details the suggested initiatives.

Fig. 4 Visualization of the result of the suggested initiatives

The implementation of these suggestions can change the degree of inventory centralization for the case company. Based on the interviews and feedback from NordicFood, the study assesses the new degree to be between 70% and 80%. Figure 4 illustrates the improvement towards MADIC.

Table 5 Suggested initiatives

Suggested change	Expected effects
Reduce number of freight providers	This change enables to achieve economies of scale in purchasing freight services. By reducing the number of transport providers used, the volumes for each carrier will be larger and contracts can be renegotiated to lower unit price. Furthermore, decreased transportation lead variability is expected.
Improve information sharing with customers by communicating earlier potential out-of-stocks and providing accurate expected delivery time	Keeping the customer informed and involved increases customer relations, increasing customer satisfaction and retention, thus generating opportunities for customer to repeat business and wider volumes.
SKU rationalization to reduce portfolio complexity and increase alignment between countries	Reducing the number of SKUs is advantageous in many aspects: it decreases aggregate demand uncertainty, thus improving forecast accuracy, it reduces complexity in supply operations, inventory levels are decreased and inventory rotation increases, and freshness of products when arriving to end-consumer is therefore improved. In addition, the change reduces the number of SKUs contributing low in sales, thus improving the profitability.
Physical centralization of the Nordic distribution network	By consolidating demand from Nordic warehouses into fewer stock points, aggregate inventory levels are reduced. Therefore, better visibility of supply and demand is achieved, better product availability and more reliable information about stock movements and stock levels. Additionally, it creates the possibility for purchasing more specialized and modern equipment, thus improving warehousing operations efficiency and increasing flexibility and agility in distribution.

In addition to the suggested changes in Table 5, the study suggests consolidating the firm's distribution structure globally. This initiative would increase supply chain efficiency and improve collaboration between entities, create shorter lead-times, and economies of scale in sourcing and distribution operations.

6 Implications for theory and practice

The section discusses how the study's findings relate to extant research and details the novelty of the study. Furthermore, the section delineates the study's relevance and usefulness for practitioners.

The study contributes to the body of inventory management literature by examining the inventory centralization problem specifically for food manufacturers. The study uses a holistic approach, which differs from the traditional mathematical modelling methodologies traditionally used in inventory management research. The study's main contributions are as the identification of key, contextual factors that influence the centralization decision for food manufacturers; the development of a method that determines a firm's MADIC; and insights from a single

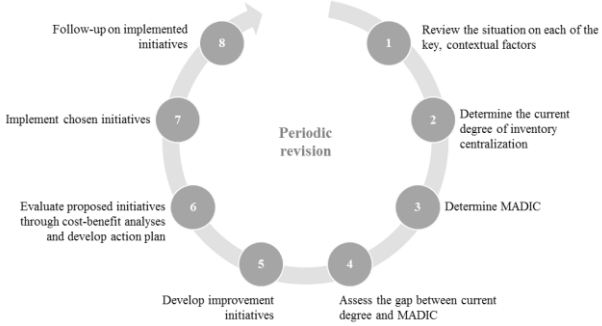

Fig. 5 Framework application procedure

case study that validates the set of key, contextual factors.

The study provides practitioners with method for assessing their MADIC. The method provides a

holistic analysis that takes all relevant, contextual factors into account, rather than simply focusing in a single factor. The method allows for adapting the weight of individual factors practitioners to include and/or exclude factors to tailoring the analysis to each firm.

The study proposes an eight-step procedure for supply chain, logistics, or inventory managers. The method is illustrated in figure 5 and detailed below:

(1) Review the situation for each of the nine factors including the strategic goals for the firm's inventory
(2) Determine the current degree of inventory centralization for the firm using definition and scale from section 2.2
(3) Determine MADIC following the procedure listed in section 4.3
(4) Compare the results obtained in step 2 and step 3, and identify the direction for moving towards MADIC
(5)Suggest improvement initiatives
(6) Decide which suggested initiatives to implement using cost-benefit analyses and develop an action plan
(7)Implement the financially feasible initiatives
(8) Follow-up on the effectiveness of implemented initiatives. Repeat the cycle by keeping into account the future markets and developments and adapt to the requirements.

This study has conducted steps 1-5 for the case firm. NordicFood conducts the remaining steps to complete the improvement process of inventory centralization. The figure is a circle suggesting that food manufacturers applying the method should conduct the process again after an appropriate period of time.

7 Conclusion

Inventory centralization is widely researched within inventory management literature. However, practically useful methods that consider the multidisciplinary nature of inventory centralization are missing. Food manufacturers face customer demands that impose increasingly complex increasingly complex on their finished goods inventories.

This study aids food manufacturers in their inventory centralization decisions by developing and testing a method for determining the most advantageous degree of inventory centralization (MADIC). The method constitutes a holistic approach that combines quantitative and qualitative techniques and integrates nine relevant factors contextual to the firm's finished goods inventories. The study presents a conceptual scale ranging from 0% to 100% inventory centralization, and using the nine identified factors, the study presents a method for determining a food manufacturers MADIC.

The paper contributes to inventory management literature by examining key factors and their influence on inventory centralization particularly for food manufacturers. For practicing managers, the study presents a useful method for evaluating a firm's MADIC. This novel decision-making framework, easily used by food manufacturers, provides relevant insights into inventory centralization decisions.

7.1 Limitations and notes for further research

This paper is not without limitations. The paper is based on literature review limited to mainstream inventory management literature and food supply chains, concerning solely finished goods. If the literature review was extended to other industries and considering other inventory types (e.g. raw materials, work in progress, spare parts), other contributions and other factors might have been identified as relevant to centralization decisions.

The study does not contain evidence applicable for statistical generalisations. Instead, the study relies on case research. The framework is validated using one case firm operating exclusively in the Scandinavian countries. Therefore, findings may not be generic across all food manufacturers.

Future research can examine the exhaustiveness of the identified factors and could extend the investigation into other industries. In addition, future research can also attempt to validate the framework with firms operating in other geographical areas. To achieve statistical generalization, additional research could be done to collect industry data through survey studies and benchmarking. Finally, future research could examine the environmental impact related to centralized vs. decentralized inventory configuration, which could be incorporated in the proposed framework as an additional factor. This would help firms focusing on not only cost-reduction and service-improvement aspects, but also environmental issues.

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