Sustainable food supply chains

the impact of automatic replenishment in grocery stores

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Published in:
Production Planning & Control

DOI (link to publication from Publisher):
10.1080/09537287.2017.1384077

Publication date:
2018

Document Version
Accepted author manuscript, peer reviewed version

Sustainable food supply chains: The impact of automatic replenishment in grocery stores

Abstract

The aim of this study is to empirically investigate the impact of automatic replenishment on food waste metrics in grocery stores. The work has been designed as a case study focusing on the replenishment process among various stores and a single warehouse. Food waste metrics of products ordered through an automatic replenishment program are compared against products ordered manually. Specifically we contrast food waste, remaining shelf life and availability at the stores for a variety of products with different shelf life. The study suggests that by utilizing an automatic replenishment program the stores can reduce their level of food waste by up to 20% and their products have a longer remaining shelf life without compromising on-shelf availability. The study also indicates that the impact of the automatic replenishment program is dependent on the product's shelf life. Those products with a shelf life of between 51 and 110 days experience the highest impact, while products with a shelf life below 30 days experience a low or even negative impact. The study extends the current understanding of automatic replenishment programs. The key point for practitioners is to apply appropriate replenishment programs according to the product characteristics and especially the shelf life.

Keywords: Information sharing; food waste; remaining shelf life; automatic replenishment; shelf life

1. Introduction

Sustainability concerns are an essential part of the operations in food supply chains. This paper focuses on the economic and indirectly the environmental dimensions of sustainability by investigating food waste metrics. It is estimated that 25%-35% of all food produced ends up as food waste (Kummu et al. 2012; Parfitt, Barthel, and Macnaughton 2010). Food waste is not only an indication of economical loss in the phase where it is discarded. It also indicates that natural resources such as soil and water has been wasted at the farm gate level and unnecessary pollution has been added to the environment from transportation along the supply chain (Bourlakis et al. 2014; Gerbens-Leenes, Moll, and Uiterkamp 2003; Maloni and Brown 2006).

Ten to twenty percent of all food waste occur at the retailer phase (Kummu et al. 2012; Parfitt, Barthel, and Macnaughton 2010). This wastage is often explained by the increasing variety and volume of fresh food products on display, a poor understanding of demand, low transparency, inadequate replenishment decisions and forecasting difficulties in a push system (Kaipia, Dukovska-Popovska, and Loikkanen 2013; Mena, Adenso-Diaz, and Yurt 2011). Also, if products arrive at the stores with a too short remaining shelf life the risk that the products may expire is higher either in the store or after the consumer takes them to their home (Kaipia, Dukovska-Popovska, and Loikkanen 2013; Mena, Adenso-Diaz, and Yurt 2011).

The replenishment decision in food supply chains is challenging because the limited shelf life require the products to move quickly from the primary producer to the end consumer, and limits the possibility of using buffer inventories (Hübner and Kuhn 2012; Kaipia, Dukovska-Popovska, and Loikkanen 2013). Also, the increasing product variety (Trienekens et al. 2012) and non-stationary demand throughout the week (Taylor and Fearne 2009) makes replenishment decisions difficult to manage. The replenishment is central for the performance of food supply chains as it balances availability on one side and the risk of food waste on the other. If too few products are ordered the stores risk a stock out and if too many are ordered the products may end spending too much time in store reducing remaining shelf life and worst-case end up being wasted.

It is estimated that half of the food losses can be prevented through better supply chain management (Kummu et al. 2012). In this regards one highly recommended remedy is better information sharing and improved replenishment decisions (Kaipia, Dukovska-Popovska, and

Loikkanen 2013; Mena, Adenso-Diaz, and Yurt 2011; Taylor and Fearne 2009). Specifically, Mena et al. (2014) propose that improved transparency of demand information upstream in the supply chain can help reduce food waste (Proposition 1b, p. 152).

To benefit from information sharing the key element is not only the information shared but also how the information is utilized by the receiving company (Baihaqi and Sohal 2013; Jonsson and Mattsson 2013; Barratt and Oke 2007). In food supply chains shared information is often utilized for replenishment decisions through an automated replenishment program (ARP) (Van Donselaar et al. 2010). The information is used to gain insight into demand and inventory levels in order to improve the replenishment decision. Theoretically, it has been demonstrated that this type of information sharing and replenishment method has a positive impact on supply chain performance such as reduced uncertainty, reduced bullwhip, reduced inventory levels or increased forecasting accuracy (Lee, So, and Tang 2000; Disney and Towill 2003; Aviv 2001; Costantino et al. 2015; Titah, Shuraida, and Rekik 2016; Kelepouris, Miliotis, and Pramatari 2008). Average performance improvement of information sharing has been reported to 1.75% (Chen 1998) and 2.2% (Cachon and Fisher 2000). However no studies have investigated the impact of these replenishment methods from a sustainability perspective. The reported performance increase varies substantially between studies and may be explained by different contingency factors such as different demand patterns, batch sizes and lead times (Jonsson and Mattsson 2013; Ketzenberg et al. 2007).

Automatic replenishment programs are enabled by an increased amount of shared information between the supply chain partners. This increased transparency makes it possible to coordinate replenishment decisions more effectively and synchronize orders to balance availability and food waste metrics. However, empirical research comparing the impact of ARP on food waste metrics and other possible contingency factors is very limited in previous research (Kaipia, Dukovska-Popovska, and Loikkanen 2013) even though it is expected to have a positive impact (Mena et al. 2014).

In this study, we empirically investigate the impact of ARP on food waste metrics in grocery stores in Norway. Specifically, we compare food waste levels and remaining shelf life at grocery stores by analyzing two situations: (1) when orders are placed manually and (2) when ordered are placed through an ARP system. We do this within a case study of a large Norwegian grocery retailer. The findings add to the research literature within this specific area specifically using a sustainability perspective.

The remainder of this paper is organized as follows. Section 2 contains a review of relevant literature for automatic replenishment programs in food supply chains. Section 3 argues for the selected case study methodology used in this study, provides a description of the cases and explains how the data has been collected and analyzed. Section 4 presents the analysis and results. In Section 5 we discuss the findings and conclude where an agenda for further research is also presented.

2. Automatic replenishment in food supply chains

To increase interfirm coordination and improve the replenishment process a number of sophisticated supply chain practices known as automatic replenishment programs (ARPs) have been developed during the last decades (Yao and Dresner 2008; Arshinder, Kanda, and Deshmukh 2008; Daugherty, Myers, and Autry 1999; Sabath, Autry, and Daugherty 2001). Automatic replenishment programs include Efficient Consumer Response from the food industry (Kurt Salamon Associates 1993), Quick Response (Daugherty, Myers, and Autry 1999), the Continuous Replenishment Program, and Vendor Managed Inventory (Yao and Dresner 2008). The logic within these ARPs is often implemented directly into the company's ERP system or as an add-on to facilitate the replenishment process.

Essentially, the ARP calculates an order proposal for each item for each store based on certain transactional information from the stores, such as point of sales (POS) data, waste data and master data such as review periods and batch sizes. The order is a proposal which can be accepted or overruled by the store management (Van Donselaar et al. 2010). However, in either case it increases the transparency for the wholesaler and enables the wholesaler to compute an estimate for future (aggregated) orders.

More specifically, the ARP functions by sharing very fine data (high granularity per stock keeping unit (SKU) level with the wholesaler's data warehouse. At the wholesaler, the POS data is used to identify seasonal and other sales patterns and generates a forecast until next delivery (where the next delivery is determined based on the lead time and the ordering frequency). The sum of this forecast and the minimum inventory level becomes the order-up-to level for the store for those particular products. The minimum inventory level is included to create an appealing shopping experience by having a minimum number of facings of a giving product (Van Donselaar et al. 2010).

If the current inventory level at the store is below the order-up-to level an order proposal is generated by computing how many batches the store needs to raise the inventory level up or above the order-up-to level. The current inventory level at the stores might be an estimate based on previous amount delivered to the store, amount wasted and the POS data.

The elements for computation of the suggested replenishment quantity to the stores can be summarized as: i) ordering frequency ii) lead time iii) batch size iv) minimum inventory level v) POS data (to generate a forecast) and i) current inventory level (Van Donselaar et al. 2010).

Characteristics specific for the food sector such as shelf life and perishability is thus not included when the automatic replenishment program computes the replenishment quantity (Van Donselaar et al. 2006; Van Woensel et al. 2007). However, inventory policies which include these aspects have previously been proposed (Bakker, Riezebos, and Teunter 2012; Broekmeulen and van Donselaar 2009; Ferguson and Ketzenberg 2006).

2.1 The role of information sharing in automatic replenishment

A key element of ARPs is the use of an increased amount of shared information from the stores to enable better decision making (Yao and Dresner 2008; Lee, So, and Tang 2000). Information sharing is often listed as one of the key features for effective coordination and performance improvements in supply chain management (Arshinder, Kanda, and Deshmukh 2008; Ganesh, Raghunathan, and Rajendran 2014; Cooper, Lambert, and Pagh 1997; Kembro, Selviaridis, and Näslund 2014). Several studies have quantified the impact of information sharing by analytical and numerical calculations in a two level dyadic or divergent supply chain (Aviv 2001; Lee, So, and Tang 2000; Raghunathan 2001; Yu, Yan, and Edwin Cheng 2001; Cachon and Fisher 2000; Jonsson and Mattsson 2013; Gavirneni, Kapuscinski, and Tayur 1999) and with multiple echelons (Wu and Cheng 2008; Chen 1998; Ganesh, Raghunathan, and Rajendran 2014; Rached, Bahroun, and Campagne 2015).

Some studies indicate a high impact on performance by sharing information while others are more conservative due to particular contingency factors (Jonsson and Mattsson 2013; Ketzenberg et al. 2007). Borrowed from contingency theory (Donaldson 2006), the underlying idea is that certain factors influence the impact of information sharing (Kembro and Näslund 2014). Or in other words, how certain strategies of information sharing fits different circumstances (Vanpoucke, Boyer, and Vereecke 2009). Table 1 summarizes some of the typical factors found in the literature that moderates the impact of information sharing. However it should not be considered as an exhaustive list. Some of the factors still lack empirical evidence and the identification of other potential contingency factors is still an open research topic (Ketzenberg et al. 2007; Giard and Sali 2013; Kembro and Näslund 2014).

Nevertheless, as ARPs are enabled by information sharing it is crucial to consider these factors when evaluating how ARP influences the performance of the company.

Table 1. Selected contingency factors which moderate the impact of information sharing

Factor	**Explanation**
Demand uncertainty	Intuitively, shared information should be used to reduce uncertainties as e.g. demand uncertainty. However, contradictory findings have been reported on this matter. Lee, So, and Tang (2000) observed that the impact of information sharing increases as the coefficient of variation (CoV) of demand increases while Chen (1998) and Ketzenberg et al. (2007) found the opposite conclusion.
Demand pattern	Jonsson and Mattsson (2013) and Gavirneni, Kapuscinski, and Tayur (1999) finds that the impact is dependent on the demand type (trend, seasonal, or promotional). E.g. sharing forecast has a higher impact than sharing POS data if demand is promotional.
Order quantity	Moinzadeh (2002) and Gavirneni, Kapuscinski, and Tayur (1999) found the highest impact of information sharing when the order quantity had moderate values compared to mean demand. If the order quantity is very large the supplier needs to start building inventory over time to accommodate demand. Thus, frequent insight into either customer demand or inventory level will only have a negligible influence on how production is planned at the supplier. On the other

	hand if the order quantity is very small orders are placed so frequently that the order itself provides sufficient information about customer demand and inventory level (Moinzadeh 2002; Gavirneni, Kapuscinski, and Tayur 1999).
Length of supply chain	The length of the supply chain can be understood as a combination of the number of echelons and the lead time between them. A general finding suggests that the impact of information sharing is higher for longer supply chains than shorter supply chains (Chen 1998; Lee, So, and Tang 2000; Moinzadeh 2002; Ganesh, Raghunathan, and Rajendran 2014; Jonsson and Mattsson 2013).
Substitution	Ganesh, Raghunathan, and Rajendran (2014) found that the demand pooling effect of product substitution decreases the impact of information sharing. i.e. if the effects of product substitution (demand pooling) is already included in the planning process, the additional impact of information sharing will be reduced especially further upstream in the supply chain.

2.2 Evaluating the impact on sustainability

Sustainability is often understood to consist of an economic, environmental and social dimension (Seuring and Müller 2008). However, we restrict our attention to evaluate the impact of ARP on food waste, remaining shelf life and availability and argue in the following why these are essential measures in food supply chains.

Firstly, in food supply chains food waste is often reported as the most important measure (Bourlakis et al. 2014; Gerbens-Leenes, Moll, and Uiterkamp 2003). A high level of food waste indicates that too many products were available, there is a loss in economic value and a waste of natural resources (Van Der Vorst 2006; Kummu et al. 2012).

Secondly, products should have a long remaining shelf life at the stores in order for consumers to buy them (Göbel et al. 2015). Longer remaining shelf life may be assumed to reduce food waste as consumers have more time to consume the products (Kaipia, Dukovska-Popovska, and Loikkanen 2013; Van der Vorst et al. 1998). Additionally, Little's law explains that if products reach the store with a longer remaining shelf life, the work in process inventory along the supply chain have been lower. Therefore, in food supply chains the remaining shelf life of products can act as a good proxy for work in progress inventory and clearly act as a measure for product quality (Van Der Vorst 2006).

Thirdly, high availability in stores is important to avoid lost sales. In practice product availability is prioritized above food waste by using high stock levels (Mena, Adenso-Diaz, and Yurt 2011) and is mostly measured at the warehouse and very rarely at the store (Aramyan et al. 2007). Therefore, a decrease in food waste at the stores and an increase in remaining shelf life is seen as an increase in performance, as availability most likely would not have been compromised.

3. Research design

The aim of this study is to empirically explore the impact of automatic replenishment programs on food waste metrics in a number of grocery stores in Norway. Based on the literature presented in Section 2, we expect to observe a lower level of food waste and a longer remaining shelf life as a result of replenishing through an ARP compared to manual replenishment.

We conduct a multiple case study approach with two cases – where the unit of analysis is the replenishment process (Yin 2013). Thus, one case where stores manually replenish products from the warehouse and one case where stores are replenishing products through an

ARP. The case study method is particularly strong for in-depth exploration of new phenomenon and causal mechanisms (Yin 2013) and as such is an appropriate method for our study. Furthermore, the use of case study research enables us to study the phenomenon in its natural context and make good use of the existing experiences (Barratt, Choi, and Li 2011). Case studies are known for investigating past or current phenomena and draws on multiple sources of evidence, such as interviews, quantitative data and observations (Voss, Tsikriktsis, and Frohlich 2002). This allowed us to investigate transactional data and to assess the food waste levels and the remaining shelf life, as well as in-depth understanding of the context and how the cases differs and operates.

3.1 Data selection process

3.1.1 Retailer selection

The study involves a large Norwegian grocery retailer consisting of a warehouse unit and a unit of fully owned stores offering a full range grocery assortment consisting of dry, frozen and fresh food products. The retailer was selected for two main reasons: (1) they are using both manual replenishment and ARP among its own warehouses and stores – making it possible to establish and compare two cases within the same retailer (Voss, Tsikriktsis, and Frohlich 2002). The material and information flow of these two replenishment methods are outlined in Figure 1. (2) A high level of trust between the researchers and the retailer had already been established through previous and on-going research activities – making it possible to get access to rather sensitive data and use snowball sampling to connect with key personnel for interviews (Patton 2002).

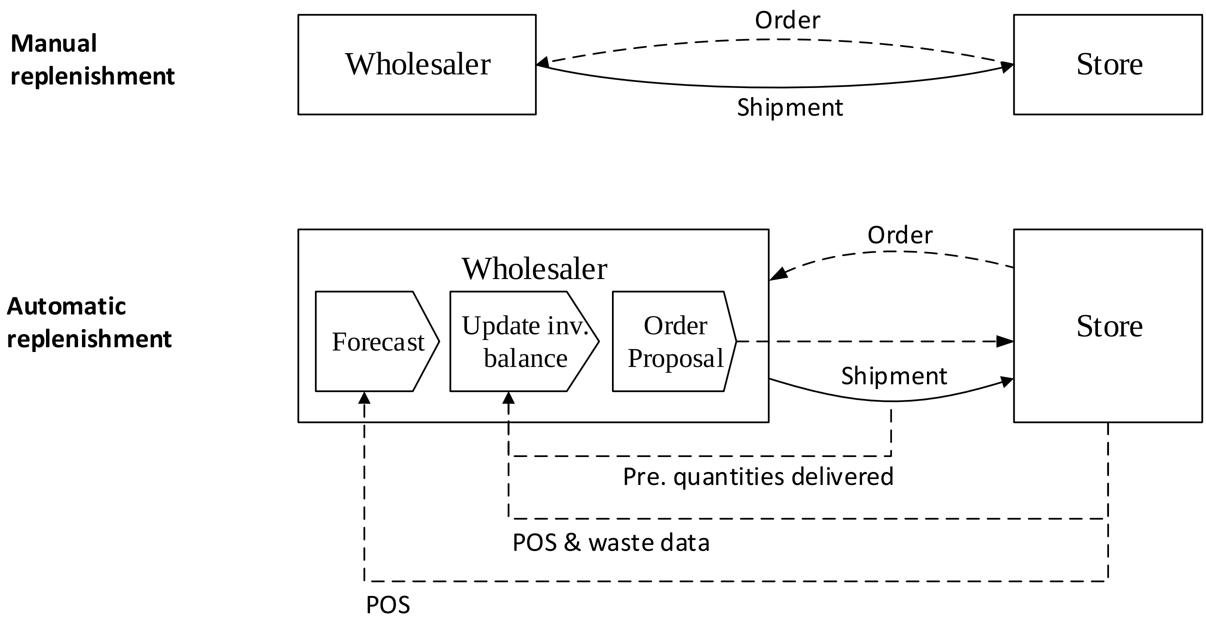

Figure 1. Flow of information and materials in the two replenishment methods

3.1.2 Case selection for investigating the impact on food waste

To compare the two replenishment methods it is essential that other factors that may influence food waste or remaining shelf life be kept constant in order to isolate the impact of the replenishment method. Table 1 presents several factors which have been identified to influence the impact of information sharing – as the ARP is enabled by information sharing these factors should be kept constant. Additionally, it has been reported that the *batch size* and the *ordering frequency* can influence food waste levels (Eriksson, Strid, and Hansson 2014; Van der Vorst et al. 1998; Chabada et al. 2015). Thus, the following selecting criteria were established to identify stores and products:

- The stores should be of the same size (physical size, opening hours, assortment, prices, campaigns, turnover and number of employees), thus experience similar demand uncertainty, demand type and substitution.

- Ordering frequency and lead time (time from ordered to delivered) should be the same to avoid influence on food waste
- Distance to the warehouse should be within one hour
- All stores have all products supplied from the same warehouse with the same batch size.
- A minimum of five stores should order the specific product with manual replenishment and a minimum of five stores with should order with the ARP i.e. a minimum 10 stores should carry the same product. These selection criteria were chosen to ensure that the data did not include any single extreme observations which may disturb the results.

We identified 21 stores and 54 products within those stores which fulfilled these criteria. One store may order some products manually and other products through an ARP, so it is not possible to completely place the stores in either the manual case or the case with ARP, this has to be done on a store product level. ie. if product A from store AA is ordered manually that particular observation (of sales, waste and shelf life) belongs to the manual case. By contrast, if product B from store BB is ordered through the ARP that observation belongs to the case with automatic replenishment. The characteristics of the two cases, i.e. the two replenishment methods are outlined in Table 2.

Table 2. Identical and different replenishment characteristics of the two cases

	Manual replenishment and ARP
Ordering frequency	All products can be ordered 3 times per week
Lead time	36-48 hours
Availability	95-98% depending on the product group

Stock rotation	Least shelf life first out	
Orders for promotions	Handled in a separate portal	
	Manual replenishment	**ARP**
Forecast	Qualitatively. Based on last week's sales and experience	Quantitatively. Based on 110 Weeks of POS data. Forecasting based on: SAP Forecasting & Replenishment module where the "best" method is selected automatically.
Inventory policy	(R,nQ) fixed review period (R); variable number of batch sizes (nQ)	(R,s,nQ) fixed review period (R); reorder point updated each review period (s); variable number of batch sizes (nQ)

3.1.3 Case selection for investigating the impact on availability and remaining shelf life

To take advantage of the case study method daily observations at two stores (out of the 21) were selected to record the remaining shelf life and availability of four products. The researchers visited these stores which also allowed for interviews with the personnel and mapping of the replenishment process. The stores and products were selected based on:

- Good reputation of the stores from the retailer (performance and willingness to collaborate)
- One store which mainly ordered with ARP and one that mainly used manual replenishment.
- Products from different product groups and with different length of shelf life to observe potential stock-outs or changes in remaining shelf life.

3.2 Data collection process

Total sales and waste data (SKU level) were collected for all 54 products for a nine month period, while the daily manual observations were conducted for a two week period. At each daily observation the inventory level including eventual stock-out situations and expiration date for the four products were recorded. Due to the time consuming nature of visiting each store every day this data collection was only possible for a limited number of stores for a two-week period.

Interviews were conducted both in the stores and at the warehouse. These interviews were conducted as semi-structured interviews to understand the identified elements from Section 2 (order frequency, lead time, forecast procedure, inventory policy, etc.) in regards to the two different replenishment processes. Insights into how the performance was perceived of the two replenishment methods were also obtained both at the warehouse and at the stores. Work experiences of the interviewees ranged from 2 years to 10+. Each interview lasted between 1-3 hours and was performed by a minimum two of the authors. Directly after the visit, the interview was documented in field notes and summarised by the researchers. Subsequently, it was sent to the company for approval and verification as well as discussed in small workshops which served as a platform for confirming and reconciling the interpretations. Table 3 summaries all collected data.

Table 3. Collected data

Type	**Description**	**Coverage**	**Purpose**
Data records	Sales of 54 products in 21 stores Waste of 54 products in 21 stores Shelf life of 54 products (master data)	Total sales and waste per product per store for nine months	Investigate the impact on food waste

Observations	Inventory level with remaining shelf life information of four products in two stores	Daily observations for 14 days	Investigate the impact on availability and remaining shelf life
Interviews (June 2015)	Store managers (2 pers.) Warehouse manager Employee responsible for ARP Employee responsible for forecasting	Between 1-3 hours per interview.	Understand the two replenishment methods and the perceived performance
Workshop (Sep. 2015)	Warehouse manager Store managers (2 pers.)	2 workshops, 2 hours each	Validate the collected data and discuss preliminary findings

3.3 Data analysis process

3.3.1 Impact on food waste

The data records of the 54 products (see Table 3) were grouped according to their shelf life as a higher food waste level was expected for products with short shelf life and less for products with long shelf life (Mena, Adenso-Diaz, and Yurt 2011). The groups (see Table 4) were formed based on the criteria of having the same range within each group (in this case ranges of 20 days) while at the same time not having too big a dispersion of the number of observations and number of products within each group. However, the first group (20 to 30 days) was used to separate products which in the literature are known as fresh food products with shelf life below 30 days (Van Donselaar et al. 2006). Due to confidentiality reasons any individual product cannot be presented with waste and sales information.

Table 4 specifies the number of data records for each group. The first group (20-30 days) consist of four products and with data from 21 stores a maximum of 84 data records in total is possible for this group. However, a total of 78 data records is included as all 21 stores did not carry all four products. Of the 78 records 29 is from stores with manual replenishment and 49 with an ARP.

The average waste percentage was calculated for each shelf life group for both replenishment methods. e.g. 49 records were used to calculate the average waste percentage for products that are ordered with ARP and have a shelf life of between 20 and 30 days.

Table 4. The number of products and data records for each shelf life group

Shelf life [days]	**Number of products**	**Typical products in this group**	**Data records**		
			Total	Manual	ARP
20-30	4	Eggs	78	29	49
31-50	13	Salmon, trout, cold cuts	225	106	119
51-70	16	Mayonnaise salads, fish cakes	270	111	159
71-90	9	Whole and sliced cheese	147	52	95
91-110	5	Butter, grated cheese	81	28	53
>110	7	Long-lasting bread and butter	133	43	90
Total	**54**		**934**	**369**	**565**

3.3.2 Impact on availability and remaining shelf life

The daily observations of the four products (see Table 3) were used to assess the on-shelf availability and calculate the average weighted remaining shelf life. The four products of minced meat, cold cuts, butter and grated cheese were selected to have products with a wide array of shelf life.

Table 5 illustrates the computations for average weighted remaining shelf life for the first day for grated cheese for replenishing with ARP. First, the remaining shelf life was extracted for each product based on the difference between the printed due date and the date the observation was made (e.g. days between 10.08.15 and 14.10.15 equals 65 days). Second, this was multiplied with the number of units with the same remaining shelf life (in this case 65 days x 55 units = 3575), and lastly the average was calculated by dividing with the total number of units.

Table 5. Calculation of average weighted remaining shelf life day 1 for grated cheese ordered with the ARP

Observation date: 10.08.15			
Due date	(1) Remaining shelf life [days]	(2) Number of units	(1) x (2)
30.09.2015	51	1	51
14.10.2015	65	55	3575
27.10.2015	78	78	6084
Total		134	9710
Average weighted remaining shelf life = 9710 / 134 = 72.5 days			

4. Analysis and results

The following two sections present the results from the quantitative data analysis together with findings from the interviews. The first section is devoted to analysis of the impact on food waste while the second section presents the findings related to availability and remaining shelf life.

4.1 The impact of ARP on food waste

Figure 2 illustrates the average food waste percentage for the six shelf life groups from Table 4. The collected data did not include any products with a shelf life below 20 days. The solid black line shows the food waste for products replenished manually while the dotted black line represents food waste for products replenished using ARP. Across all shelf life groups, the average food waste for products ordered manually is 7.3% compared to 6% for products ordered with ARP.

During the interviews, the responsible employees for the ARP and forecasting explained that an internal pilot study was conducted before rolling out ARP. During that pilot study it was observed products with a shelf life below 20 days should be kept for manual replenishment as it resulted in inadequate order proposals. This also explains why the collected data did not include any observations of products with shelf life below 20 days.

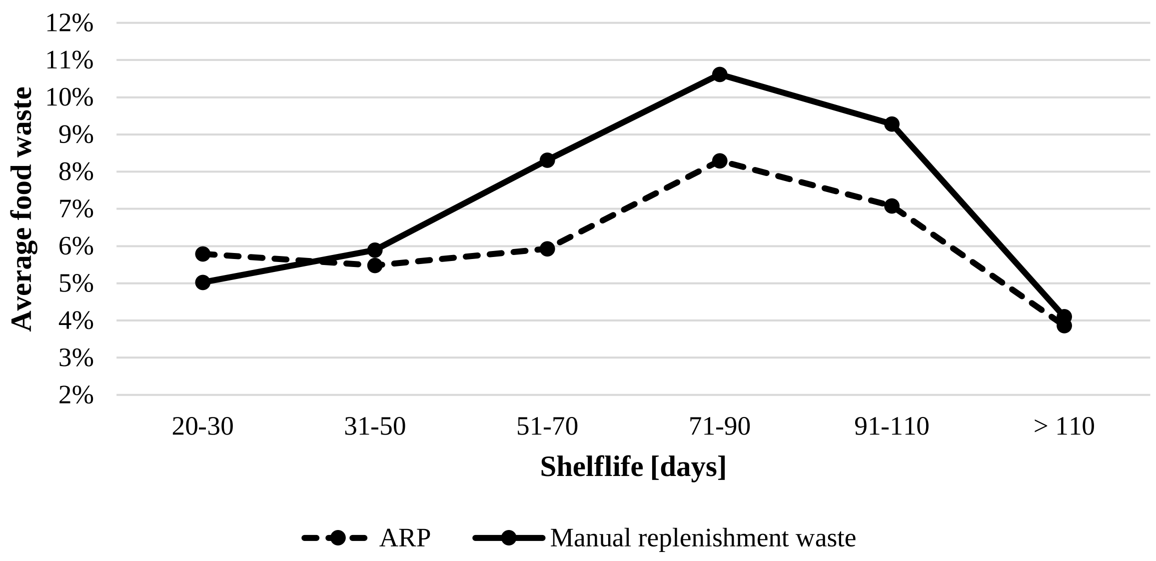

Figure 2. Food waste for a nine month period for ARP and manual replenishment

From Figure 2, we can make a general observation that, irrespective of the replenishment method, there is increasing food waste for products with a medium-long shelf life (between 51-110 days of shelf life). The group with the highest food waste consists primarily of different types of sliced and whole cheese. The two groups with lowest food waste, shelf life between 20-30 days and above 110 days are mainly eggs and breads with long shelf life. This is in line with the findings from (Eriksson, Strid, and Hansson 2014) who consecutively found a higher waste percentage for cheese than eggs.

Secondly, reading figure 2 strictly, it indicates that ARP is favorable in all shelf life groups except for short shelf life products (below 30 days). More interestingly, the impact of

ARP is biggest for those shelf life groups where the food waste is highest. There is a small improvement for product groups with shelf life between 31-50 days and above 110 days, however the improvement for products with shelf life between 51 and 110 days is a reduction of more than 20% (2% points) for these three groups. In other words, the impact of ARP appears to be dependent on product characteristics such as shelf life. The collected data was total sales for nine months and it was not possible to describe nor investigate the influence of other characteristics as e.g. demand patterns or demand uncertainty. However, as elaborated in table 1, other factors may influence the impact of information sharing and should be further investigated based on empirical insights.

4.2 The impact of ARP on availability and remaining shelf life

Figure 3 shows the average weighted remaining shelf life for the four products for the two different replenishment methods. The grey line represents products ordered manually while the black line represents products that are ordered with ARP. A clear tendency of a longer remaining shelf life, or better freshness, for products that are ordered with ARP can be observed. Across the four products, the remaining shelf life is 5.2% higher for products ordered with ARP compared to products ordered manually.

The difference between the two replenishment methods increases in a similar pattern to what was observed in Figure 2. i.e. for products with a medium-long shelf life (not *remaining* shelf life but the prescribed shelf life from production to expiration date, e.g. butter and grated cheese) the improvement is higher than for products with a short shelf life (e.g. cold cuts). For cold cuts, the improvement went from 30.8 days of remaining shelf life to 31.3 days of remaining shelf life, giving only a small increase of 1.6%. However, for grated cheese the remaining shelf life increased from an average of 66.8 days for manual replenishment to 71.5 days for replenishment with ARP giving a 7% improvement in remaining shelf life.

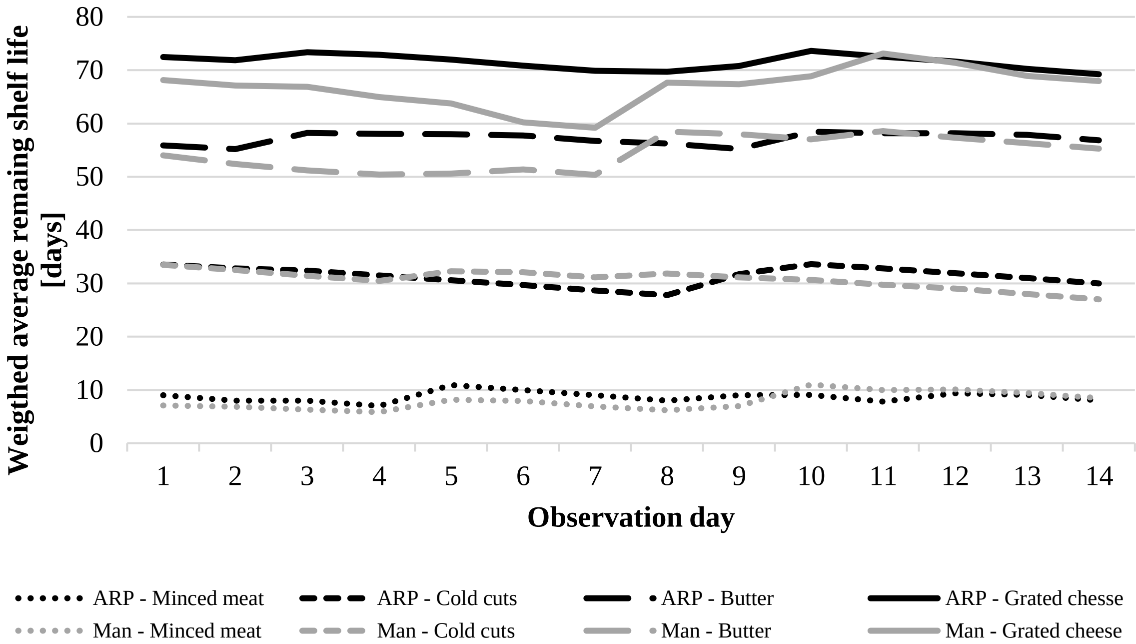

Figure 3. Average weighted remaining shelf life for replenishing with ARP and manual replenishment. Two week period with four products.

In the two week period of data collection the shelves were never observed to be empty and some products even had extra stock in the backroom of the store. This indicates a high level of availability for both replenishment methods. Additionally, it was noticed in the interviews that, based on the results from the retailer's own internal pilot study, stores with ARP experienced a 2-3% increase in availability (assuming that the stores had a yearly turnover of 1.2 million euro to ensure a satisfactory inventory turnover and stability for using ARP).

Also, from the interviews it was confirmed that for ARP to function it requires high quality data, e.g. it is important that the number of products on the shelves is aligned with the information in the system. Poor quality data would result is inadequate order proposals from the ARP. As a result, store managers have the option to overrule the order proposal from the

ARP but this was mainly applied during the implementation phase until the ARP is fine turned.

Compared to manual replenishment the store managers explained that ARP required less experience and training and highlighted how this was apparent during sick leave and vacations where manual replenishment was challenging. The warehouse manager also added that using ARP makes the replenishment process more standardized. Ideally, this would result in a more consistent experience (related to availability and remaining shelf life) for the consumers across stores.

5. Discussion and conclusion

The aim of this study was to empirically explore the impact of automatic replenishment on food waste and remaining shelf life in a Norwegian grocery store chain. The study contrasted manual replenishment method with an automated one. The study demonstrated that the use of automatic replenishment has a positive impact on reducing food waste and increasing remaining shelf life of some food products. The improvement from automatic replenishment is highest for products with a shelf life between 51 and 110 days where the food waste reduction exceeds 20% (2% points) for the products analyzed. Unexpectedly, this group also represents the products with the highest food waste levels in the study. It was expected that the very fresh product category (shelf life below 30 days) had the largest waste levels as these products are highly time sensitive and are commonly known for having high food waste (Mena, Adenso-Diaz, and Yurt 2011; Kaipia, Dukovska-Popovska, and Loikkanen 2013). The waste level for the products with a long shelf life were low as expected, but it is somewhat interesting that the utilization of automatic replenishment did not seem to have a significant impact on food waste for this group.

The discussion of these results is separated into three main subsections. First, we discuss how the findings can extend the current body of knowledge of automatic replenishment and information sharing and how it affects sustainability measures. Afterwards we focus on the financial impact and place the findings in a managerial context to assess its implications. Lastly, we discuss the limitations of this study and propose important paths for future research.

5.1 Extension of literature

It has been proposed that increased information sharing of demand information upstream in the supply chain could contribute to decreased food waste in the supply chain (Mena et al. 2014). Also, empirical research establishing and investigating the relation between information sharing and performance is scarce (Baihaqi and Sohal 2013; Kembro and Näslund 2014). This study used an automatic replenishment program as a proxy for information sharing and investigated how it affects performance of certain sustainability measures.

We empirically investigated the relation between the use of automatic replenishment and food waste metrics in grocery stores. The findings suggest a positive relationship although modest in size. The impact may be as high as 20% for certain products, which can be used as an initiative for stores to engage in (more) information sharing activities. The findings add to the limited amount of literature which investigates how information sharing impacts food waste and the remaining shelf life. Similar to Kaipia, Dukovska-Popovska, and Loikkanen (2013) the findings show an improvement in both performance measures and supports proposition 1b by Mena et al. (2014).

Table 1 highlights how the impact of information sharing has been previously discussed to be dependent on certain contingency factors. If information is shared and used through an automatic replenishment program in a food context, Figure 2 and 3 suggests the impact of shared information depends on the shelf life of the product. The interesting question is why this dependency appears. A plausible explanation is that the POS and waste data do not provide sufficient information to support the complexity for replenishing products with a short shelf life. Here, additional information such as remaining shelf life, quality, appearance or an estimate of one of these might be necessary to share as well to improve the replenishment decision. This type of information is available with manual replenishment, thus there is a more complete picture of how the situation is, and could explain why it performs better for products with a shelf life between 20-30 days. When the shelf life is medium to medium-long (see Figure 3) it gets less complicated to make the replenishment decision and here POS data and waste data can be of great value for making replenishment decisions. For products with a long shelf life the replenishment decision might have little impact on the level of food waste and improving the replenishment decision for these products may therefore not show up as less food waste.

The dependency of shelf life for some products adds to the theoretical understanding of information sharing in supply chains. It has been proposed in numerous studies that the impact of information sharing is dependent on several factors, such as demand uncertainty, lead times and order quantities. However, this study proposes a new additional contingency factor by suggesting that, in a food context, the value of shared information is dependent on the shelf life of the products.

From a sustainability perspective, the findings indicate that the use of automatic replenishment contributes to a more sustainable food supply chain with less food waste and provides consumers with fresher products without harming availability. Obviously, reduced food waste is an economical gain for the companies involved in the chain, but reducing food waste at stores and improving remaining shelf life at consumers will, over time, require less food to be produced and transported from the primary producers to the final consumer. This contributes to a preservation of natural resources and limits the impact on the environment.

5.2 Managerial and financial implications

From a managerial perspective, the findings highlight that food waste is not only an issue for products with a shelf life below 30 days but also for products with medium to long shelf life. The use of an automatic replenishment program is a valuable remedy for decreasing food waste at stores for products with medium-long shelf life while maintaining the availability of products.

By using an automatic replenishment program the stores were able to obtain a 5.2% improvement in freshness and 1.3% lower food waste. An average reduction of food waste of 1.3% might not sound substantial and practitioners may find the impact too small to act upon. However, it should be taken into account that this is a net loss in profit for the individual store. If put into a broader context, namely the Norwegian grocery market, it becomes more interesting. The total profit in 2014, of the three largest grocery retailers in Norway, was 366 million Euro and a total turnover of 16,775 million Euro giving an average earning of 2.2%. If the 1.3% waste could be eliminated this would potentially increase the average earnings to 3,5%. In other words, an increase in profit with another 218 million Euro to a total of 584 million Euro in profit (some of the savings is of course already realized as some stores have implemented automatic replenishment). Additionally, savings for transportation, energy, water and cropland up through the supply chain is possible. Through better transparency the wholesaler would also be able to improve its own inventory performance (not just at the stores) an improvement that previously has been reported to be between 1.75% and 2.2% (Cachon and Fisher 2000; Chen 1998).

Overall, the results indicate that it is beneficial to utilize automatic replenishment for replenishment decisions in the food industry. However, some differentiating or tailoring of the replenishment system is needed for products with a short shelf life. Additionally, proper governance structures should be formulated for the ownership of the shared data, especially if the retailer and the wholesaler are two independent companies. If multiple retailers use the same wholesaler a neutral third party company could be introduced to receive the information and handle the automatic replenishment program. This will reduce the risk of competitors getting access to sensitive data.

5.3 Limitations and further research

The study has several limitations that should be used to guide further research. The study only includes a limited number of products for investigating the impact on availability and remaining shelf life in food stores in Norway. However, the small sample suggests that there is a possible improvement and for future research this should be scrutinized further with more products and a longer time period.

It has previously been highlighted how different demand patterns may influence the impact of information sharing. This could be further investigated for new empirical insights. The collected data in this study was the total sales for nine months and therefore a further analysis of demand patterns was not possible. Likewise, the data did not include products with a shelf life below 20 days. It should be investigate if sharing point-of-sales and waste data for these more perishable products are sufficient or if sharing more detailed information are needed and profitable to improve the replenishment decision (Huang, Li, and Ho 2015). This additional information may include inventory levels with remaining shelf life or estimated remaining shelf life based on temperature log (Ketzenberg, Bloemhof, and Gaukler 2015). This type information could not only be used for establishing more advanced inventory policies (Cannella, Ciancimino, and Framinan 2011; Cannella 2014; Costantino et al. 2015), but also used to make suggestions for highly relevant initiatives such as timely markdowns, shop by shop promotions or trans-shipments between nearby stores on the same delivery route.

Substitution among products may also be an important factor to consider for improving the replenishment decision further (Ganesh, Raghunathan, and Rajendran 2014). If the products are ordered manually, the manager may choose to order less of one specific product if he observes a high stock level of a substituting product with short remaining shelf life (in order to sell this first). The system that utilizes the shared information does not have this possibility and controls each product individually and will react more slowly to substitution signals. This is further supported by Van Woensel et al. (2007) who suggest that automatic replenishment for perishable items with short shelf life should be separate for non-perishable products and include the substitution effect.

6. Acknowledgements

The authors gratefully acknowledge the assistance provided by the Norwegian Research Council (NRC) for the financial support of Retail Supply Chain 2020. Also, we would like to thank the participating case company which together with the NRC enabled this study. We would like to thank Anita Romsdal, Jan Ola Strandhagen and Cecilia Haskins for their helpful comments and suggestions. Lastly, we would like to thank Chris Martin for assistance in editing this paper.

7. References

Aramyan, Lusine H, Alfons GJM Oude Lansink, Jack GAJ Van Der Vorst, and Olaf Van Kooten. 2007. "Performance measurement in agri-food supply chains: a case study." Review of. *Supply Chain Management: An International Journal* 12 (4):304-15.

Arshinder, Arun Kanda, and S. G. Deshmukh. 2008. "Supply chain coordination: Perspectives, empirical studies and research directions." Review of. *International Journal of Production Economics* 115 (2):316-35. doi: 10.1016/j.ijpe.2008.05.011.

Associates, Kurt Salmon. 1993. "Efficient Consumer Response: Enhancing Consumer Value in the Grocery Industry,." In. The Research Department Food Marketing Institute, Washington.

Aviv, Yossi. 2001. "The effect of collaborative forecasting on supply chain performance." Review of. *Management science* 47 (10):1326-43.
Baihaqi, Imam, and Amrik S Sohal. 2013. "The impact of information sharing in supply chains on organisational performance: an empirical study." Review of. *Production Planning & Control* 24 (8-9):743-58.
Bakker, Monique, Jan Riezebos, and Ruud H Teunter. 2012. "Review of inventory systems with deterioration since 2001." Review of. *European journal of operational research* 221 (2):275-84.
Barratt, Mark, Thomas Y Choi, and Mei Li. 2011. "Qualitative case studies in operations management: Trends, research outcomes, and future research implications." Review of. *Journal of Operations Management* 29 (4):329-42.
Barratt, Mark, and Adegoke Oke. 2007. "Antecedents of supply chain visibility in retail supply chains: a resource-based theory perspective." Review of. *Journal of Operations Management* 25 (6):1217-33.
Bourlakis, Michael, George Maglaras, David Gallear, and Christos Fotopoulos. 2014. "Examining sustainability performance in the supply chain: The case of the Greek dairy sector." Review of. *Industrial Marketing Management* 43 (1):56-66.
Broekmeulen, Rob ACM, and Karel H van Donselaar. 2009. "A heuristic to manage perishable inventory with batch ordering, positive lead-times, and time-varying demand." Review of. *Computers & Operations Research* 36 (11):3013-8.
Cachon, Gérard P, and Marshall Fisher. 2000. "Supply chain inventory management and the value of shared information." Review of. *Management science* 46 (8):1032-48.
Cannella, S., E. Ciancimino, and J. M. Framinan. 2011. "Inventory policies and information sharing in multi-echelon supply chains." Review of. *Production Planning & Control* 22 (7):649-59. doi: 10.1080/09537287.2010.512276.
Cannella, Salvatore. 2014. "Order-up-to policies in information exchange supply chains." Review of. *Applied Mathematical Modelling* 38 (23):5553-61.
Chabada, Lukas, Heidi Carin Dreyer, Hans Henrik Hvolby, and Kasper Kiil. 2015. Linkage Between Delivery Frequency and Food Waste: Multiple Case Studies of a Norwegian Retail Chain. Paper presented at the IFIP International Conference on Advances in Production Management Systems.
Chen, Fangruo. 1998. "Echelon reorder points, installation reorder points, and the value of centralized demand information." Review of. *Management science* 44 (12-part-2):S221-S34.
Cooper, Martha C, Douglas M Lambert, and Janus D Pagh. 1997. "Supply chain management: more than a new name for logistics." Review of. *The International Journal of Logistics Management* 8 (1):1-14.
Costantino, Francesco, Giulio Di Gravio, Ahmed Shaban, and Massimo Tronci. 2015. "The impact of information sharing on ordering policies to improve supply chain performances." Review of. *Computers & Industrial Engineering* 82:127-42.
Daugherty, Patricia J, Matthew B Myers, and Chad W Autry. 1999. "Automatic replenishment programs: an empirical examination." Review of. *Journal of business logistics* 20 (2):63-82.
Disney, Stephen M, and Denis R Towill. 2003. "The effect of vendor managed inventory (VMI) dynamics on the Bullwhip Effect in supply chains." Review of. *International Journal of Production Economics* 85 (2):199-215.
Donaldson, Lex. 2006. "The contingency theory of organizational design: challenges and opportunities." In *Organization Design*, 19-40. Springer.

Eriksson, Mattias, Ingrid Strid, and Per-Anders Hansson. 2014. "Waste of organic and conventional meat and dairy products—A case study from Swedish retail." Review of. *Resources, Conservation and Recycling* 83:44-52.

Ferguson, M., and M. E. Ketzenberg. 2006. "Information sharing to improve retail product freshness of perishables." Review of. *Production and Operations Management* 15 (1):57-73.

Ganesh, M., S. Raghunathan, and C. Rajendran. 2014. "The value of information sharing in a multi-product, multi-level supply chain: Impact of product substitution, demand correlation, and partial information sharing." Review of. *Decision Support Systems* 58:79-94. doi: 10.1016/j.dss.2013.01.012.

Gavirneni, Srinagesh, Roman Kapuscinski, and Sridhar Tayur. 1999. "Value of information in capacitated supply chains." Review of. *Management science* 45 (1):16-24.

Gerbens-Leenes, PW, HC Moll, and AJM Schoot Uiterkamp. 2003. "Design and development of a measuring method for environmental sustainability in food production systems." Review of. *Ecological Economics* 46 (2):231-48.

Giard, Vincent, and Mustapha Sali. 2013. "The bullwhip effect in supply chains: a study of contingent and incomplete literature." Review of. *International Journal of Production Research* 51 (13):3880-93.

Göbel, Christine, Nina Langen, Antonia Blumenthal, Petra Teitscheid, and Guido Ritter. 2015. "Cutting Food Waste through Cooperation along the Food Supply Chain." Review of. *Sustainability* 7 (2):1429-45.

Huang, Yeu-Shiang, Ming-Chi Li, and Jyh-Wen Ho. 2015. "Determination of the optimal degree of information sharing in a two-echelon supply chain." Review of. *International Journal of Production Research*:1-17.

Hübner, Alexander H, and Heinrich Kuhn. 2012. "Retail category management: State-of-the-art review of quantitative research and software applications in assortment and shelf space management." Review of. *Omega* 40 (2):199-209.

Jonsson, Patrik, and Stig-Arne Mattsson. 2013. "The value of sharing planning information in supply chains." Review of. *International Journal of Physical Distribution & Logistics Management* 43 (4):282-99.

Kaipia, Riikka, Iskra Dukovska-Popovska, and Lauri Loikkanen. 2013. "Creating sustainable fresh food supply chains through waste reduction." Review of. *International Journal of Physical Distribution & Logistics Management* 43 (3):262-76.

Kelepouris, T., P. Miliotis, and K. Pramatari. 2008. "The impact of replenishment parameters and information sharing on the bullwhip effect: A computational study." Review of. *Computers and Operations Research* 35 (11):3657-70. doi: 10.1016/j.cor.2007.04.004.

Kembro, Joakim, and Dag Näslund. 2014. "Information sharing in supply chains, myth or reality? A critical analysis of empirical literature." Review of. *International Journal of Physical Distribution & Logistics Management* 44 (3):179-200.

Kembro, Joakim, Kostas Selviaridis, and Dag Näslund. 2014. "Theoretical perspectives on information sharing in supply chains: a systematic literature review and conceptual framework." Review of. *Supply Chain Management: An International Journal* 19 (5/6):609-25.

Ketzenberg, Michael, Jacqueline Bloemhof, and Gary Gaukler. 2015. "Managing Perishables with Time and Temperature History." Review of. *Production and Operations Management* 24 (1):54-70.

Ketzenberg, Michael E, Eve D Rosenzweig, Ann E Marucheck, and Richard D Metters. 2007. "A framework for the value of information in inventory replenishment." Review of. *European journal of operational research* 182 (3):1230-50.

Kummu, M, H De Moel, M Porkka, S Siebert, O Varis, and PJ Ward. 2012. "Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use." Review of. *Science of the Total Environment* 438:477-89.

Lee, Hau L, Kut C So, and Christopher S Tang. 2000. "The value of information sharing in a two-level supply chain." Review of. *Management science* 46 (5):626-43.

Maloni, Michael J, and Michael E Brown. 2006. "Corporate social responsibility in the supply chain: an application in the food industry." Review of. *Journal of business ethics* 68 (1):35-52.

Mena, Carlos, B. Adenso-Diaz, and Oznur Yurt. 2011. "The causes of food waste in the supplier–retailer interface: Evidences from the UK and Spain." Review of. *Resources, Conservation and Recycling* 55 (6):648-58. doi: 10.1016/j.resconrec.2010.09.006.

Mena, Carlos, Leon A. Terry, Adrian Williams, and Lisa Ellram. 2014. "Causes of waste across multi-tier supply networks: Cases in the UK food sector." Review of. *International Journal of Production Economics* 152:144-58. doi: 10.1016/j.ijpe.2014.03.012.

Moinzadeh, Kamran. 2002. "A multi-echelon inventory system with information exchange." Review of. *Management science* 48 (3):414-26.

Parfitt, Julian, Mark Barthel, and Sarah Macnaughton. 2010. "Food waste within food supply chains: quantification and potential for change to 2050." Review of. *Philosophical Transactions of the Royal Society B: Biological Sciences* 365 (1554):3065-81.

Patton, Michael Quinn. 2002. *Qualitative Research & Evaluation Methods*. Vol. 3rd Edition: SAGE Publications, Inc.

Rached, M., Z. Bahroun, and J. P. Campagne. 2015. "Assessing the value of information sharing and its impact on the performance of the various partners in supply chains." Review of. *Computers and Industrial Engineering* 88:237-53. doi: 10.1016/j.cie.2015.07.007.

Raghunathan, Srinivasan. 2001. "Information sharing in a supply chain: A note on its value when demand is nonstationary." Review of. *Management science* 47 (4):605-10.

Sabath, Robert E, Chad W Autry, and Patricia J Daugherty. 2001. "Automatic replenishment programs: The impact of organizational structure." Review of. *Journal of business logistics* 22 (1):91-105.

Seuring, Stefan, and Martin Müller. 2008. "From a literature review to a conceptual framework for sustainable supply chain management." Review of. *Journal of cleaner production* 16 (15):1699-710.

Taylor, David H., and Andrew Fearne. 2009. "Demand management in fresh food value chains: a framework for analysis and improvement." Review of. *Supply Chain Management: An International Journal* 14 (5):379-92. doi: 10.1108/13598540910980297.

Titah, Ryad, Shadi Shuraida, and Yacine Rekik. 2016. "Integration Breach: Investigating the Effect of Internal and External Information Sharing and Coordination on Firm Profit." Review of. *International Journal of Production Economics*.

Trienekens, JH, PM Wognum, Adrie JM Beulens, and Jack GAJ van der Vorst. 2012. "Transparency in complex dynamic food supply chains." Review of. *Advanced Engineering Informatics* 26 (1):55-65.

Van Der Vorst, Jack GAJ. 2006. "Performance measurement in agri-food supply-chain networks." In *Quantifying the agri-food supply chain,* edited by C.J. Ondersteijn, J.H. Wijnands, R.B. Huirne and O. van Kooten, 15-26. Springer.

Van der Vorst, JGAJ, Andrie JM Beulens, W de Wit, and P van Beek. 1998. "Supply chain management in food chains: Improving performance by reducing uncertainty." Review of. *International Transactions in Operational Research* 5 (6):487-99.

Van Donselaar, K, Tom van Woensel, RACM Broekmeulen, and J Fransoo. 2006. "Inventory control of perishables in supermarkets." Review of. *International Journal of Production Economics* 104 (2):462-72.

Van Donselaar, Karel H, Vishal Gaur, Tom Van Woensel, Rob ACM Broekmeulen, and Jan C Fransoo. 2010. "Ordering behavior in retail stores and implications for automated replenishment." Review of. *Management science* 56 (5):766-84.

Van Woensel, Tom, Karel Van Donselaar, Rob Broekmeulen, and Jan Fransoo. 2007. "Consumer responses to shelf out-of-stocks of perishable products." Review of. *International Journal of Physical Distribution & Logistics Management* 37 (9):704-18.

Vanpoucke, Evelyne, Kenneth K. Boyer, and Ann Vereecke. 2009. "Supply chain information flow strategies: an empirical taxonomy." Review of. *International Journal of Operations & Production Management* 29 (12):1213-41. doi: 10.1108/01443570911005974.

Voss, Chris, Nikos Tsikriktsis, and Mark Frohlich. 2002. "Case research in operations management." Review of. *International Journal of Operations & Production Management* 22 (2):195-219.

Wu, YN, and TC Edwin Cheng. 2008. "The impact of information sharing in a multiple-echelon supply chain." Review of. *International Journal of Production Economics* 115 (1):1-11.

Yao, Yuliang, and Martin Dresner. 2008. "The inventory value of information sharing, continuous replenishment, and vendor-managed inventory." Review of. *Transportation Research Part E: Logistics and Transportation Review* 44 (3):361-78.

Yin, Robert K. 2013. *Case study research: Design and methods*. Fifth ed: Sage publications.

Yu, Zhenxin, Hong Yan, and TC Edwin Cheng. 2001. "Benefits of information sharing with supply chain partnerships." Review of. *Industrial management & Data systems* 101 (3):114-21.