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A stochastic micro-periodic age-based inventory replenishment policy for perishable goods

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ABSTRACT

In this paper, we propose a micro-periodic inventory replenishment policy for quickly perishable goods with fixed and known lifetime of items, deterministic lead time, fixed given order cycle, mixed issuing policies (FIFO and LIFO), age-based stock, imperfect items and target customer service level under random demand. The inventory policy is based on time of day (morning, midday, afternoon or evening). The results of our simulation study show that the proposed micro-periodic inventory policy leads to waste reduction of 66% as well as a partial decrease in cost compared to inventory policy with planning on a daily basis.

1. Introduction

A globally acknowledged problem is food waste where roughly one-third of the edible parts of food produced for human consumption is lost or wasted globally, which amounts to approximately 1.3 billion tons per year (Fao, 2013). Food is wasted from the initial agricultural production to the final household consumption. Additionally, in many countries, food loss occurs at retail levels. For example, Germany's retail and wholesale alone produces 550,000 tons of waste per year (Kranert et al., 2012). Grocery waste is primarily made up of quickly perishable goods with a lifetime between three and five days, such as fresh fruits, vegetables, meat, fish, dairy products, and baked goods. According to the study of (Kranert et al., 2012), the non-optimal inventory management of quickly perishable goods is one of the most frequent causes of the waste problem in grocery retail.

An *inventory management* deals with the questions: when should an order be placed and what quantities should be ordered (Nahmias, 2011)? Inventory replenishment policies fall into one of two categories: a periodic or continuous inventory control. The classic (R, S) *periodic inventory control policy* (*order-up-to-level policy*) has a fixed order cycle R and dynamic order quantity q where S is the target order level (Tempelmeier, 2011). An *order cycle R* is the average time between two subsequent orders. The classic *continuous inventory control policy* (s, S) or (s, Q) (reorder point policies) assume a continuous inventory review and the reorder point occurs when the level of inventory drops below or is equal to the inventory level s. The inventory policy (s, Q) has a constant order quantity Q. Otherwise it is the (s, S) policy with a dynamic order quantity q. The application of these policies for perishable goods needs to consider the lifetime of these products (Nahmias, 2011). There are many inventory systems for perishable items which we describe in short in Section 2.

Under *FIFO (First-In-First-Out) issuing policy*, any demand is satisfied with the oldest goods, and in the *LIFO (Last-In-First-Out)*

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issuing policy, the freshest goods are withdrawn first from physical stock. Under *mixed FIFO and LIFO issuing policy*, it is understood that some of the customers in grocery stores take the freshest goods first and other customers take the oldest products from the shelf, simultaneously. *Example:* The stock has 20 items, 3 items of the stock have the age of one day, 13 items have the age of five days and the remaining 4 items have the age of six days. The maximum lifetime H of all items is seven days. Because customers in the grocery store withdraw the items with a mixed FIFO and LIFO principle, we describe here a possible scenario. The customer demand is 10 items. For example, 50% of items will be withdrawn according to the FIFO principle and 50% according to the LIFO principle. In other words, 5 items of the stock are withdrawn according to the FIFO principle and 5 items according the LIFO principle. With the LIFO principle, 3 items with the age of one day and 2 items with the age of five days are withdrawn from the stock. With the FIFO principle, 1 item with the age of five days and 4 items of the age six days are withdrawn from the stock. The remaining stock in the store is 10 items with the age of five days.

Classically, grocery retail uses a daily inventory control (Gaur and Fisher, 2004) and daily delivery for quickly perishable goods with a fixed lifetime between 3 and 7 days (Weteling, 2013). Daily planning equates to a macro-period planning. A day is a *macro-period* and a time of day (morning, midday, afternoon or evening) is a *micro-period*. Although macro-periodic replenishment policies have been successfully established in real-life, they are not optimal for quickly perishable goods, as is evident from the waste problem in grocery retail (Kranert et al., 2012).

According to the work of van Donselaar and Broekmeulen (2012), a strong relation exists between key performance indicators (customer service level, cost etc.), parameters (fixed lifetime, order cycle etc.) of a perishable inventory system and outdating. The level of customer service can be increased at the request of the decision makers in grocery stores. However, the increase in the customer service leads to an increase of safety stock. The high safety stock leads to higher storage costs and to more wastes. The outdating of perishable items leads directly to the waste problem in grocery retail. Analogous to van Donselaar and Broekmeulen (2012), we assume that the decrease of the mean stock level can reduce waste quantity in grocery stores. The decrease of the mean stock level can be achieved through (1) a shortened order cycle and (2) more frequent delivery of quickly perishable goods. The change of both planning parameters leads to a planning in micro-periods because daily inventory control is typical in grocery retail. For the planning in micro-periods, we developed a *new inventory replenishment policy* with micro-periodic control. This policy allows inventory control and delivery of grocery stores several times daily. We assume that micro-periodic inventory control can reduce waste in grocery stores more than macro-periodic inventory replenishment policy (on a daily basis).

Micro-periodic inventory control is not entirely new, but it leads to questions in the context of the waste problem in grocery retail. The *goal of this paper* is to clarify these two open questions:

1. How much can the micro-periodic inventory control reduce food waste quantities?
2. What is the effect on the total cost for perishable goods?

We apply the *methodological approach*, consisting of steps as presented in Fig. 1: In *step zero*, we identify the waste problem in grocery retail. In *step one*, we describe the relevance of our work and develop a new micro-periodic replenishment policy for quickly perishable goods. In the *second step*, we create a simulation study using rolling planning in a prototypical supermarket chain and compare the simulation results of micro- versus macro-periodic replenishment policies.

The practical significance of our work lies in a new solution approach to reduce waste in grocery stores. We propose twice daily

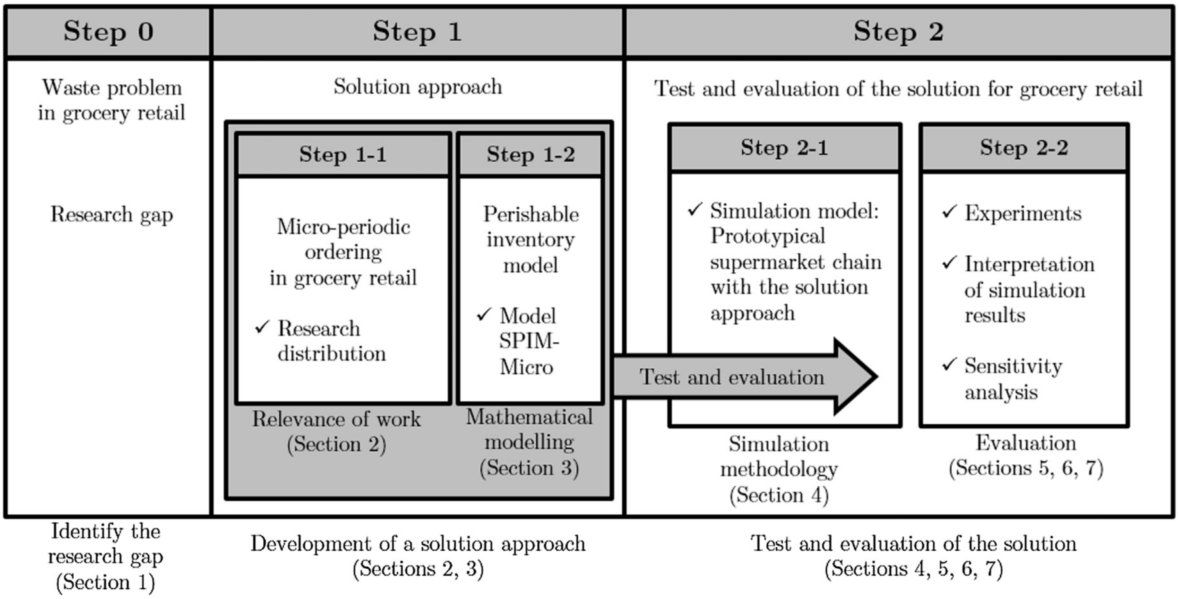

Fig. 1. The methodological approach in this work.