Reducing Food Waste and Boosting Profits through Inventory Management: The Case of Small Slovenian Bakeries

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This article explores the role of inventory management in reducing food waste and improving economic performance in selected Slovenian bakeries, contributing to a more efficient, environmentally responsible and sustainable economy. Using semi-structured interviews with key bakery personnel and an in-depth analysis of business documentation, our study applies the Economic Order Quantity (EOQ) model and Newsvendor model to test the following two hypotheses: (H1) improving inventory management at Bakery 1 can reduce total annual procurement costs by more than 15% without causing spoilage or raw material waste, and (H2) minimizing food waste at Bakery 2 may not necessarily align with maximizing profit. The findings confirm that applying these models can enhance production and procurement planning, demonstrating that while cost reductions and waste minimization are achievable, they may not always be fully aligned. The study underscores the importance of strategic inventory management in balancing financial and environmental objectives in small bakeries.

Keywords: EOQ and Newsvendor inventory management models, inventory optimization, food waste minimization, sustainable economy, Slovenia

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Introduction

Food waste is a pressing global issue with profound economic, environmental, and ethical implications. It is estimated that approximately 1.3 billion tons of edible food, or one-third of global food production, is lost or wasted annually (Goossens et al. 2019, 1). Despite growing awareness and various initiatives, food waste remains a major challenge, contributing significantly to sustainability issues and resource depletion (Riesenegger et al. 2023). In particular, the food supply chain – extending from farmers to final consumers – creates waste at every stage, including raw material acquisition, production, distribution, and retail (Osojnik Črnivec et al. 2021, 8; Seminar 2016, 17; Kennard 2019). Food waste leads to substantial resource losses (Osojnik Črnivec et al. 2021, 42–48; Ministrstvo za kmetijstvo, gozdarstvo in prehrano 2021, 20–21; Šubic 2023; Álvarez-de-los-Mozos, Badurdeen, and Dossou 2020, 1795; Dora et al. 2019, 48–49; Parfitt et al. 2010; Gunders 2012, 10–11; CARE-4CLIMATE 2022).

The growing global population, expected to reach 9.6 billion by 2050, further intensifies the strain on resources like food, water, and energy (Hafyan et al. 2024, 1). In this context, food waste exacerbates environmental degradation and economic losses, as resources invested in producing discarded food are essentially wasted (Lin et al. 2018; Handayati and Widyanata 2024).

Among food categories, bread is one of the most wasted products globally. With annual bread production exceeding 100 million tons, estimates suggest that hundreds of tons are discarded daily (Rejeb et al. 2022, 1). In developed countries, more than half of all bread produced is wasted, primarily due to overproduction and unsold inventory (Rejeb et al. 2022, 1–2; Hafyan et al. 2024, 2). While a significant portion of this waste occurs at the end of the supply chain, bread-making also generates waste throughout the production and distribution process (Hafyan et al. 2024, 2). Despite this, food waste solutions in the industry have largely focused on managing surplus rather than addressing the root cause of overproduction, leaving a critical gap in waste prevention efforts.

The existing literature on food waste solutions largely focuses on managing surplus through initiatives like redistribution systems, dynamic pricing, and food-sharing platforms, while ignoring the foundational issue of production planning (Li 2022; Caldeira et al. 2019, 31; Riesegger et al. 2023, 2). These interventions tend to be reactive, stepping in when waste has already occurred rather than preventing overproduction and inefficient resource use upfront. Moreover, food-sharing platforms, although well-intentioned, may unintentionally incentivize overproduction by creating financial incentives to generate surplus (Almeida Oroski and Silva 2023, 816–827). This reactive, surplus-focused approach does not address inefficiencies in production planning, where waste originates.

To problematize this issue, our study critically examines the unintended consequences of existing food waste interventions and explores alternative solutions. In particular, we focus on small bakeries, where bread waste is prevalent, and where production planning inefficiencies contribute significantly to food waste. The gap in the literature is clear: while there is substantial research on inventory models for perishables, few studies explicitly consider how these models can address food waste in the bakery sector. Our study seeks to close this gap by proposing a proactive approach that focuses on production planning rather than post-production waste management.

To address this gap, we apply two widely used inventory models – the Economic Order Quantity (EOQ) model and the Newsvendor model – to help small bakeries optimize their procurement and production processes. By applying these models, we aim to help small bakeries make more informed production decisions, reducing waste at its source and improving profitability.

The main contribution of our study lies in the tailored application of inventory models to small bakeries, an area that has been underexplored in current research. While large-scale bakeries benefit from advanced forecasting tools, small bakeries often face tight margins and limited resources. Our study demonstrates how simple, yet effective inventory models can address the specific challenges faced by small bakeries, helping them achieve sustainable operations while enhancing financial performance. Furthermore, by focusing on data-driven strategies for demand forecasting and waste reduction, our research provides bakery owners with practical tools for sustainable decision-making that can be easily implemented in their daily operations.

In the following section, we provide a theoretical background and literature review, highlighting key findings and gaps in the existing research. The methodology section outlines the research design, data collection, and analytical techniques employed. The results and analysis section presents the key findings and interprets their significance. Finally, the conclusion and policy implications section summarizes the key insights, discusses the broader implications, and offers recommendations for policymakers and future research.

Theoretical Background and Literature Review

Food waste presents significant environmental, social, and financial concerns, with its impact increasing as it moves further down the supply chain (Al-Obadi et al. 2022). Ocicka and Raźniewska (2018, 549) emphasize that the most costly losses occur in later stages due to higher processing and distribution expenses. Since food processing serves as the link between agricultural production and consumers, enhancing efficiency at this stage is crucial. Raak et al. (2017, 5) argue that identifying and mitigating the factors contributing to food waste during processing is key to developing effective prevention strategies.

Mohamed (2024, 3–4) underscores the importance of inventory management in food waste prevention, as it directly influences efficiency, customer satisfaction, and overall profitability. By strategically balancing total costs, product availability and procurement optimization, businesses can significantly reduce waste. However, Sonko and Akinlabi (2020, 13), and Yavari et al. (2020) point out that managing perishable goods presents unique challenges, as their quality declines over time, making timely inventory control essential.

Vu et al. (2022, 103) and Huang et al. (2021, 4) advocate for a proactive approach to food waste management, aligning with the waste management hierarchy, which ranks prevention as the most effective method. Rather than focusing on redistribution or disposal, businesses should prioritize strategies such as demand forecasting, production planning, and inventory optimization to prevent surplus before it occurs. Riesenegger et al. (2023, 2) reinforce this perspective, referencing the United Nations Environment Programme (UNEP) food waste hierarchy, which emphasizes prevention as the most effective strategy for reducing waste at its source.

Rahal (2024) stresses the importance of optimization models in improving decision-making within perishable supply chains, enabling businesses to minimize losses while maintaining service levels. In the bakery sector, Nansubuga et al. (2024) identify lean inventory systems and strong supplier relationships as key factors in aligning supply with demand to mitigate waste. Given the short shelf life of bakery products, particularly bread, achieving this balance remains a pressing challenge.

Duarte et al. (2021) demonstrate that integrating forecasting methods with inventory planning can significantly reduce waste during the production phase of bakery operations. Gioia et al. (2022) further argue that perishable inventory management requires tailored strategies that account for limited shelf life and fluctuations in demand, ensuring that businesses avoid both overproduction and underproduction. Hofer (2020) highlights the ongoing challenge companies face in balancing inventory size and costs – while businesses strive to maintain sufficient inventory to meet customer demand, the associated financial risks drive them to minimize stock levels.

EOQ MODEL

To address these challenges, inventory models provide structured solutions for managing perishable food stocks. The Economic Order Quantity (EOQ) model is a fundamental tool in inventory management, balancing ordering and holding costs to minimize total inventory-related expenses and maximize profitability (Venilla and Karthikeyan 2024, 3003; Morufu and Olayimika 2016, 95). Despite being introduced over a century ago by Ford W. Harris (Harris 1913), the model remains highly relevant due to its simplicity and effectiveness in optimizing stock levels. Andriolo et al. (2013), Prameswari et al. (2024, 390) and Kurniawan et al. (2024, 29) further highlight the model's relevance for perishable goods, as it prevents excess stock that may lead to obsolescence or waste while ensuring a sufficient supply to meet demand.

The EOQ model has been widely applied in the food and beverage industry, where managing perishable inventory is essential to maintaining product quality (Widiastini et al. 2019; Annisa et al. 2023; Nagib et al. 2016). EOQ can therefore be particularly useful in bakery operations where ingredient procurement must be carefully managed to balance cost efficiency and product freshness. Since the stock cycle for perishable goods must not exceed their shelf life, applying EOQ with constraints specific to perishability ensures better control over waste (Macías-López et al. 2021, 3). To account for perishability constraints, researchers have explored adaptations of the model to address real-world complexities, such as fluctuating demand, bulk discounts, and deteriorating items (Alnahhal et al. 2024, 1; Mehta 2023; Patriarca et al. 2020; Zeng et al. 2019; Toles 2018). These enhancements make EOQ a relevant and adaptable tool for modern inventory challenges.

EOQ was chosen for this study because it provides a structured yet flexible approach to managing ingredient procurement in small bakeries. Unlike more complex inventory models that may require extensive computational resources or real-time data inputs, EOQ offers a practical solution that aligns with the operational scale of small businesses. By determining the optimal order size, bakeries can avoid unnecessary storage costs, reduce spoilage, and improve cost efficiency.

Newsvendor Model

The Newsvendor model is widely used for perishable products with short shelf lives (Riesenegger et al. 2023, 9). This single-period inventory model focuses on determining the optimal stock level for a given period, helping businesses balance the risks of overstocking and understocking.

One of the key challenges in bakery inventory management is forecasting demand accurately (Hall and Kronberg 2023). Seasonal fluctuations and consumer preferences introduce stochastic variations that make demand difficult to predict, increasing the likelihood of stockouts or surplus. Overstocking leads to excessive waste, particularly for perishable items, while unsold products occupy valuable storage space and increase holding costs. Conversely, stockouts can result in lost sales, dissatisfied customers and necessitate more expensive emergency procurement (Khan et al. 2023, 2460; Kurniawan et al. 2024; Sonko and Akinlabi 2020, 13). Riesenegger et al. (2023, 4) highlight how growing consumer preference for fresh products further complicates inventory decisions, as customers often select items with longer expiration dates, leaving older stock unsold. This behaviour underscores the importance of dynamic inventory policies that adapt to changing demand patterns and consumption behaviours.

Anitha et al. (2023) argue that improper inventory management, such as inaccurate demand forecasting and rigid replenishment policies, contributes significantly to food waste.

The Newsvendor model provides a structured approach to mitigating these risks by incorporating demand probability distributions and cost trade-offs between excess inventory and shortages (Solari et al. 2024, 1234). Recognizing that demand distributions are often unknown in practice, Castro Moraes and Yuan (2021) and Liu and Zhang (2023) propose data-driven methods that maximize expected profit by determining inventory and pricing levels based on historical demand and feature data.

Bakeries must find an optimal balance between availability and waste reduction. The Newsvendor model facilitates this by optimizing production levels based on demand probabilities while considering waste minimization strategies such as, according to Riesenegger et al. (2023, 4), discounting near-expiry products. Additionally, the Newsvendor model has been effectively applied in retail business to perishable goods like fresh produce, which share similar inventory challenges with bakery products (Chen et al. 2017; Keskin et al. 2021).

THE RESEARCH GAP

The current literature extensively acknowledges the environmental, financial, and operational impact of food waste in the supply chain, particularly within food processing and bakery operations (Raak et al. 2017; Mohamed 2024; Vu et al. 2022). While various studies emphasize the importance of inventory optimization and the applicability of EOQ and Newsvendor models for perishable goods (Riesenegger et al. 2023; Kurniawan et al. 2024; Prameswari et al. 2024), the engagement often remains at a conceptual or simulation-based level, lacking empirical validation within small-scale, real-world bakery contexts. Furthermore, although researchers have proposed model adaptations for perishability constraints and demand variability, few have critically examined how such models interact with the operational limitations and sustainability goals of micro-enterprises.

This gap becomes especially evident in bakery settings, where balancing cost-efficiency and waste reduction involves daily trade-offs influenced by shelf life, consumer behaviour, and resource constraints. Our study directly addresses this underexplored intersection by applying EOQ and Newsvendor models to two Slovenian bakeries using actual business data and interviews, thereby offering a grounded contribution to the literature. It demonstrates that while these models can indeed optimize procurement and reduce waste, economic and environmental goals may not always align perfectly, highlighting the need for nuanced, context-sensitive inventory strategies in small food enterprises.

Purpose, Objectives, and Hypotheses

The purpose of this research is to investigate, through the case study of two selected Slovenian bakeries, how improved inventory management could enhance economic performance and reduce food waste, thereby contributing to a more efficient, sustainable, and environmentally friendly economy.

To achieve this purpose, we set the following objectives:

- to identify the challenges faced by the selected small Slovenian bakeries in inventory management,
- to determine the demand forecasting methods employed by the selected bakeries,
- to explore how the selected bakeries manage potential excess inventory, and

- using the classical EOQ model (economic order quantity), the EOQ model with quantity discounts, and the Newsvendor model, to define possible solutions for more effective inventory management and production planning to minimize food waste and improve economic results in the selected bakeries.
- In the subsequent research, we tested the validity of the following two research hypotheses:

H1: *By improving inventory management, Bakery 1 could reduce total annual procurement costs by more than 15% without causing spoilage or waste of raw materials.*

H2: *The goal of minimizing food waste at Bakery 2 may not necessarily align with the goal of maximizing profit.*

This research integrates the EOQ model for ingredient purchasing with the Newsvendor model for daily production planning. This dual-model approach ensures better alignment between stock levels and demand fluctuations. Our research extends the application of these models beyond individual case studies, offering a replicable framework for bakeries facing similar inventory challenges. The findings provide practical insights for small and medium-sized bakeries looking to balance cost efficiency, demand variability, and waste reduction – an area where research, according to Vu et al. (2022, 124), remains limited in developed countries. The study aligns with broader sustainability goals while enhancing the financial viability of food businesses.

Methodology

This chapter outlines the methods used to achieve the objectives, as well as the description of the sample, the instrument, and the data processing procedure.

DATA COLLECTION METHODS AND APPLICATION OF THE EOQ AND THE NEWSVENDOR MODEL

To achieve the set goals and test the proposed hypotheses, we first reviewed relevant literature related to optimizing food supply chains, the issue of food waste, modelling, and inventory management. In this process, we used the comparison method, through which we compared and evaluated the findings and views of different authors on inventory management. As part of our research, we collected primary data through business documentation from companies and semi-structured interviews with representatives from two selected Slovenian bakeries. These data were analysed using content analysis, while quantitative data were statistically processed. In the case of the first bakery, the data were applied within the framework of the classical EOQ model and the EOQ model with quantity discounts, while in the case of the second bakery, the data were applied within the framework of the Newsvendor model/ stochastic demand model for a single period to improve inventory management and optimization.

EOQ model

The EOQ model helps determine the optimal inventory quantity that meets demand while minimizing annual costs and waste (Fernando 2024). The classic EOQ model is based on several assumptions, which simplify the real-world situation to make the model work effectively. Here are the key assumptions of the EOQ model (Muller 2011, 127–128):

- Demand rate is known, continuous, constant, independent and uniform over time. In reality, demand often fluctuates seasonally or daily.
- No stockouts are allowed (the model assumes there are no shortages; demand is always met).
- All costs are precisely known and do not change (there are fixed order costs – each order has a fixed cost, regardless of the order size – and constant holding costs – the cost to hold or store inventory is known and constant per unit per time period).
- Lead time is zero (the time between placing an order and receiving it is fixed and known). In reality, suppliers may have inconsistent lead times.
- Each order is delivered individually.
- Only one product is considered, which means there are no savings from consolidating multiple items into a single order. The EOQ model typically applies to a single product or item.
- Inventory is replenished instantly once the order arrives (no gradual stock build-up).
- The purchase price per unit is constant (i.e. there are no bulk discount incentives)

The inventory cycle involves three variables: (i) the order quantity Q which is the fixed order size always placed; (ii) the cycle time T which is the time between two consecutive orders and depends on the order quantity; and (iii) the demand D which represents the number of units needed in stock during a given period. Only the order quantity is directly under our control. The quantity entering inventory during the cycle is Q while the quantity exiting is D × T. These two quantities must be equal because the inventory level at the beginning and end of the cycle is zero.

The total cycle cost consists of three components. The product of UC (cost per unit) × D (demand) represents the fixed unit cost component.

$$\frac{RC \times D}{Q}$$

represents the vari1able component of the inventory acquisition cost (the number of orders placed during the cycle = 1) while

$$\frac{HC \times Q \times T}{2}$$

represents the variable component of the inventory holding cost (T = holding time; Q/2 = average inventory level). Therefore, the total cost per cycle is:

$$UC \times Q + RC + \frac{HC \times Q \times T}{2}.$$

The total cost per cycle is divided by the cycle length T, resulting in the total cost per unit of time:

$$TC\ (total\ \cos t) = \frac{UC \times Q}{T} + \frac{RC}{T} + \frac{HC \times Q}{2}$$

We know that or . When we substitute this into the equation, we get:

$$TC = (UC\, x\, D) + \frac{RC \times D}{Q} + \frac{HC \times Q}{2}$$

The inventory holding cost component increases linearly while the inventory acquisition cost component decreases with the order quantity. The total cost curve takes the form of an asymmetric 'U' with a distinct minimum that corresponds to the optimal order quantity. For orders smaller than the optimum, total costs increase due to higher inventory acquisition costs while for orders larger than the optimum, costs rise due to higher inventory holding costs. The optimal order quantity is determined by taking the derivative of the total cost function concerning quantity and setting it equal to 0:

$$\frac{d(TC)}{d(Q)} = -\frac{RC \times D}{Q2} + \frac{HC}{2} = 0.$$

We solve for Q to obtain the optimal quantity:

$$EOQ = Qo = \sqrt{\frac{2 \times RC \times D}{HC}}$$

We know that . In the equation, we replace with and solve for the optimal cycle length :

$$To = \frac{Qo}{D} = \sqrt{\frac{2 \times RC}{D \times HC}}$$

The unit cost in the total cost formula is fixed. Therefore, we focus on the part that forms the variable costs:

$$VC\ (variable\ \cos ts) = \frac{RC \times D}{Q} + \frac{HC \times Q}{2}.$$

The optimal variable costs are obtained by substituting *Q* with *Qo* in the *VC* equation. The result is compared with *Qo* and it is found that VCo = HC × Qo. The optimal cost per unit of time is the sum of the fixed and variable components:

$$TCo = UC\ x\ D + VCo$$

The inventory acquisition costs and inventory holding costs are equal at the economically optimal order quantity: .

$$\sqrt{\frac{RC \times HC \times D}{2}}.$$

$$VC_o = RC \times D \times \sqrt{\frac{HC}{2 \times RC \times D}} + \frac{HC}{2} \times \sqrt{\frac{2\ x\ RC\ x\ D}{HC}}$$

$$= \sqrt{\frac{RC \times HC \times D}{2}} + \sqrt{\frac{RC \times HC \times D}{2}}$$

$$= \sqrt{2 \times RC \times HC \times D}.$$

The EOQ model may suggest a decimal value for goods that can only be purchased in discrete units. Suppliers may not offer standard package sizes, delivery is made with vehicles of fixed capacities, etc. Sometimes, it is necessary to round the order quantity. Variable costs near the optimal order quantity remain quite stable. We compare the minimum variable costs VCo at the optimal order quantity Qo with the variable costs and get (Waters 2003, 69–73, 77–80):

$$\frac{VC}{VCo} = \frac{RC \times D}{Q \times HC \times Qo} + \frac{HC \times Q}{2 \times HC \times Qo}$$

When we use $Qo = \sqrt{\frac{(2 \times RC \times D)}{HC}}$, we get:

$$\frac{VC}{VCo} = \frac{1}{2} \times \left(\frac{Qo}{Q} + \frac{Q}{Qo}\right)$$

The assumption that the lead time is 0 and the goods arrive as soon as the order is placed seldom holds in practice. It is in the interest of all stakeholders to minimize the lead time. If both the lead time and demand are constant, it makes sense to schedule orders so that they arrive before the existing inventory is exhausted. The reorder level is expressed as (Bussom 2014):

$$ROL = lead\ time\ (LT) \times demand\ per\ unit\ of\ time\ (D).$$

Unlike the classical EOQ model, the EOQ model with quantity discounts assumes that costs change with the volume of purchases. The EOQ model assumes stable conditions where the goal is to minimize costs in the long term.

Newsvendor model

Sometimes, however, models for a shorter period, even for just one period, are necessary. For example, a newspaper seller wants to have enough copies to meet demand on Sunday morning. If he buys too many copies from the wholesaler, he is left with unsold inventory that becomes worthless by the end of the day. If he buys too few copies, there is unmet demand, which could have generated more profit (Hofer 2020). In such cases, the Newsvendor model can be used to determine the optimal quantity.

The Newsvendor model (also called the Single-Period Inventory Model) is used for inventory decisions involving perishable or seasonal items – like newspapers, fashion items, or holiday products – where you only get one chance to order before demand is realized. Assumptions of the Newsvendor model are:

- *Single Selling Period*: the product is sold during a single, finite time period (no replenishment is possible). In our case study this period is one day.
- *Uncertain Demand*: demand is a random variable with a known probability distribution.
- *Single Order Decision*: only one order is placed before the selling season begins; no reordering.
- *Known Costs:* the model assumes known unit cost (c), selling price (p), and salvage value (v) or stockout cost.
- *Overage and Underage Costs:* the model balances overage cost (Co), which is a cost of ordering too much (leftover inventory), and underage cost (Cu), which is a cost of ordering too little (lost sales).
- *Instantaneous Delivery:* the entire order arrives before the selling period starts (no lead time issues).
- *No Holding Beyond the Period:* unsold inventory is either discarded, salvaged at a lower value, or has no value after the period.

Assuming the newspaper seller buys Q copies, the following applies:

- If the demand D is greater than Q, the seller sells all the copies and generates a profit of $Q \times (SP - UC)$ (assumption: no penalty for lost sales).
- If the demand D is smaller than Q, the seller sells D newspapers at full price and receives the value SV for each remaining newspaper Q – D. In this case, the profit is $D \times SP + (Q - D) \times SV - Q \times UC$.

The optimal value for Q maximizes the expected profit. To simplify the calculation, let us assume that $SV = 0$. In this case, we obtain values for demand, profit, and probability, as shown in Figure 1. The expected profit *EP(Q)* from purchasing Q newspapers is the sum of the profits, each multiplied by its respective probability.

$$\begin{aligned} EP(Q) &= \sum(\text{expected profits when } D < Q) \\ &\quad + \sum(\text{expected profits when } D \geq Q) \end{aligned}$$

$$= \sum_{D=0}^{Q} [D \, x \, SP - Q \times UC] \times Prob(D) + \sum_{D=Q+1}^{\infty} Q \, x \, [SP - UC] \times Prob(D)$$

$$= SP \times \left[\sum_{D=0}^{Q} D \times Prob(D) + Q \times \sum_{D=\ Q+1}^{\infty} Prob(D) \right] - Q \times UC.$$

Demand	Profit	Probability
0	0 × SP – Q × UC	Prob(0)
1	1 × SP – Q × UC	Prob(1)
2	2 × SP – Q × UC	Prob(2)
⋮	⋮	⋮
Q – 1	(Q – 1) × SP – Q × UC	Prob(Q – 1)
Q	Q × (SP – UC)	Prob(Q)
Q + 1	Q × (SP – UC)	Prob(Q + 1)
⋮	⋮	⋮
∞	Q × (SP – UC)	Prob(∞)

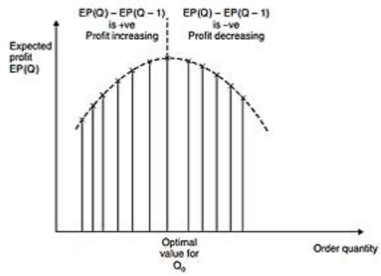

FIGURE 1 Demand, Probability of Sale, and Expected Profit from Purchasing Each Copy

SOURCE Waters (2003)

The expected profit increases with the order quantity until it reaches a maximum, after which it starts to decline.

If $EP(Q) - EP(Q-1)$ is a positive number, the profit from additional copies of the newspaper increases.

If $EP(Q) - EP(Q-1)$ is a negative number, the profit from additional copies decreases.

The optimal order quantity Qo is the point at which the profit starts to decrease if an additional copy is purchased (see Figure 1). We have found $EP(Q)$. If we substitute $(Q-1)$ instead of Q, we get the expected profit if the newspaper seller buys $(Q-1)$ copies of the newspaper (Waters 2003, 156–159; Cachon and Terwiesch 2013, 250–254):

$$EP(Q-1) = SP \times \left[\sum_{D=0}^{Q-1} D \times Prob(D) + (Q-1) \times \sum_{D=Q}^{\infty} Prob(D)\right] - (Q-1) \times UC$$

$$EP(Qo+1) - EP(Qo) = SP \times \left[\sum_{D=Qo+1}^{\infty} Prob(D) - \frac{UC}{SP}\right].$$

We want to find a point where the following holds:

$$EP(Qo) - EP(Qo-1) > 0 > EP(Qo+1) - EP(Qo)$$

or

$$SP \times \left[\sum_{D=Qo}^{\infty} Prob(D) - \frac{UC}{SP}\right] > 0 > SP \times \left[\sum_{D=Qo+1}^{\infty} Prob(D) - \frac{UC}{SP}\right]$$

We get:

$$Prob(D \geq Qo) > \frac{UC}{SP} > Prob(D \geq Qo + 1)$$

Including SV, we obtain the final result:

$$Prob\ (D \geq Qo) > \frac{UC - SV}{SP - SV} > Prob(D \geq Qo + 1).$$

SAMPLE DESCRIPTION

The interviews were conducted with the management of both bakeries, specifically with the proxy of Bakery 1 and the founder of Bakery 2. Both interviewees are men, approximately 30 years old. The first interviewee is an economist by profession and took over the bakery from his father while the second is a chef who, after several years of experience at a renowned Slovenian restaurant, decided to embark on an independent path. Bakery 1 has been in operation since 1987 and has a significantly longer history compared to Bakery 2, which was founded in 2020. Bakery 1 employs around 20 people across its four locations while Bakery 2 has 3 full-time staff members. In addition to its bakery offerings, Bakery 1 also specializes in pastry making while Bakery 2 provides catering services and supports the organization and execution of various events. To facilitate this, Bakery 2 has established contractual partnerships with eight waiters and five chefs.

DESCRIPTION OF THE INSTRUMENT

Primary data was collected through semi-structured interviews. The questions were sent to the interviewees in advance via email. To ensure better understanding, we also provided sub-questions for each main question. Later, due to a tight schedule, we arranged a phone interview with the proxy of Bakery 1 to discuss the questions, while the interview with the owner of Bakery 2 took place at the company's headquarters. This allowed us to clarify each question in more detail. We assume that both interviewees understood the questions correctly and answered honestly and that the quantitative data from the business documents they provided were accurate and precise. The interviews were designed with 10 main open-ended questions prepared in advance, which served as the starting point for the conversations.

Moreover, these interviews were specifically designed to elicit the quantitative data required for inventory optimization models. During each interview, targeted questions were asked to obtain concrete figures on product demand (e.g. number of units sold the previous day), purchase and selling prices, holding and ordering costs, delivery lead times, and spoilage or waste rates. In many cases, participants referred to their records on the spot or provided detailed estimates based on their operational routines. These data points, supplemented by the documentation they shared (e.g. stock reports and sales logs), were used as direct inputs for the quantitative models presented in the analysis.

After receiving responses to these questions, we were able to ask additional questions on various topics, as the conversation naturally unfolded. We were careful not to influence the responses with our questions, aiming to let the interviewees speak as much as possible, with the interviewer speaking as little as possible. The questions in the semi-structured interview addressed the following topics: types of inventory in the bakery, challenges faced by the bakery in inventory management, production planning, management of surplus inventory, inventory valuation methods, and raw material procurement.

DATA PROCESSING DESCRIPTION

The data obtained through the interviews were analysed using content analysis for the part where we were interested in the opinions and perspectives of the interviewees. The numerical data from the business documentation regarding production were statistically processed and used within the framework of the EOQ and Newsvendor models for inventory management. Geographically, the study was limited to the selected bakeries in Slovenia (specifically in the Savinja Valley region). In terms of time, the study was set in 2024 and limited to the period from February 17, 2023, to May 10, 2024. In terms of subject matter, it primarily focused on the operational function of inventory management, which is an important aspect of business economics in the context of food waste issues. Since this is a case study of two selected bakeries, the generalizability of the research findings should be understood in this context.

Results and Analysis

Based on the data obtained from the companies' business documentation and through the interviews, we subsequently analysed inventory management in the selected bakeries. Using two theoretical models, we identified potential solutions for more efficient inventory management and production planning in both bakeries.

BAKERY 1

Bakery 1 is a small artisanal bakery that engages in both retail and wholesale. The bakery primarily holds stock of materials and raw ingredients, such as various types of flour, yeast, salt, sugar, margarine, and butter. They do not have semi-finished products but do carry some retail goods for sale in their stores. The assortment of finished products is stable in 90% of cases and includes bread, pastries, potica (Slovenian cake), cookies, and homemade noodles.

The bakery strives to manage its raw material inventory efficiently to maintain the freshness and quality of its products. According to them, key factors are the availability and price they can negotiate with suppliers. They try to acquire raw materials with shorter shelf lives on a weekly basis or even twice a week. For flour, they have silos with a capacity of 4.8 tonnes, which allows them to store and purchase larger quantities, resulting in a better price for the flour. White and semi-white flour are ordered every month and a half, while the other ingredients are ordered monthly. For wholesale, there is a regular daily ordering system, which allows for a good estimate of the quantity of products the bakery needs to provide. For retail, the estimate is based on past trends.

Products that are not sold are redistributed for animal feed, with 4% of the total daily production being sold for this purpose. The value of these products, based on the original price, is on average 80% lower. White bread is turned into breadcrumbs.

The bakery operates on average 5 days a week, 50 weeks a year. For both retail and wholesale, they produce an average of 120 loaves of white and semi-white bread and an additional 40 loaves of other types of bread daily. Yeast, sugar, and salt are purchased for all bread types together. On average, they use 120 kg of white and semi-white flour, 160 cubes of yeast (0.04 kg each), 2.6 kg of sugar, and 2.2 kg of salt per day. The procurement costs for new stock are €10 for flour, €14.50 for yeast, €8.36 for sugar, and €12.10 for salt. The supplier covers the delivery costs of all ingredients. Storage and insurance costs are 30% per year for flour, 20% per year for yeast, 19% per year for sugar, and 15% per year for salt. The ingredients are ordered in advance and at fixed intervals, regardless of the current demand for bread. Additionally, the demand for bread in both retail and wholesale is relatively stable. We therefore treated the demand for bread ingredients as stable and independent of fluctuations in the demand for white and semi-white bread, which allowed us to analyse the situation using the EOQ model and calculate the optimal order quantity, total annual procurement costs, and total variable costs:

$$EOQ = Qo = \sqrt{\frac{2 \times RC \times D}{HC}}$$

$$TC = (UC\ x\ D) + \frac{RC \times D}{Q} + \frac{(HC \times Q)}{2} \quad VC = \frac{RC \times D}{Q} + \frac{HC \times Q}{2}.$$

Quantity discounts for purchasing larger quantities of flour, as well as the corresponding holding costs (HC), are shown in Table 1.

The annual consumption of white and semi-white flour in the bakery is 30,000 kg. The bakery currently orders 3,600 kg of flour every 6 weeks. With this quantity, the total costs amount to €9,856 per year. This is not the optimal quantity because, at the optimum, the equality $RC = HC$ must hold. We calculated the optimal quantity using the standard procedure for the model with quantity discounts. The discounts result in a stepped, discontinuous total cost curve. The minimum point of each curve is represented by *Qoi*. We know that:

$$Qoi = \sqrt{\frac{2 \times RC \times D}{I \times UCi}}$$

For each curve, the minimum is either valid or invalid. It is valid if it falls within the order quantity range at a specific cost per unit, and invalid if it falls outside this range (Bolton 2023). The valid total cost curve always increases to the left of the valid minimum. This means that the valid minimum of the total cost curve must be at or to the right of the minimum at the break-even point. We calculated the EOQ at the lowest price

TABLE 1 Purchase Prices for Flour with Quantity Discounts

Unit cost (UC)		Holding costs (HC)
0–24 kg:	€0.52/kg	0.52 × 0.3 = €0.156
25–99 kg:	€0.46/kg	0.46 × 0.3 = €0.138
100–499 kg:	€0.40/kg	0.40 × 0.3 = €0.12
500–1,999 kg:	€0.36/kg	0.36 × 0.3 = €0.108
2,000–4,999 kg:	€0.32/kg	0.32 × 0.3 = €0.096
5,000–7,499 kg:	€0.29/kg	0.29 × 0.3 = €0.087
7,500–9,999 kg:	€0.27/kg	0.27 × 0.3 = €0.081
10,000 kg:	€0.25/kg	0.25 × 0.3 = €0.075

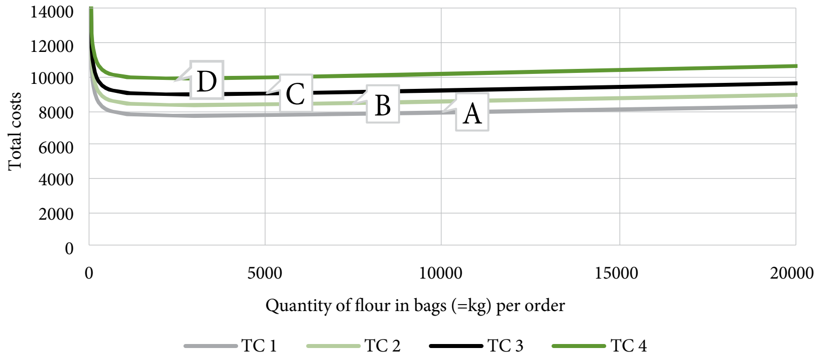

FIGURE 2 Total Cost Curves (in EUR)

per unit, but the calculated quantity was not within the corresponding quantity range. This was an invalid minimum. We then calculated the total annual costs at the break-even point for a quantity of 10,000 kg (point A in Figure 2). Similarly, the minimum of the second (TC 2) and third total cost curve (TC 3) was also invalid. Therefore, we calculated the total costs at the break-even points B and C (see Figure 2). When calculating the EOQ for TC 4, the quantity was within the corresponding quantity range. This was a valid minimum. We then determined the total costs at the valid minimum, obtaining point D (see Figure 2).

In the end, we compared the solutions.

- Point A: Q = 10,000 kg, TC = €7,905 p.a.
- Point B: Q = 7,500 kg, TC = €8,444 p.a.
- Point C: Q = 5,000 kg, TC = €8,978 p.a.
- Point D: Q = 2,500 kg, TC = €9,840 p.a.

While the classic EOQ model assumes a constant unit purchase price, this study introduces all-units quantity discounts for flour. This accurately reflects real supplier pricing and enables cost saving through bulk procurement. To accommodate this, the model evaluates total costs – including ordering, holding and purchasing costs – across discount tiers, selecting the quantity that minimizes overall cost rather than only the EOQ formula output. This increases the model's practical relevance.

The lowest total costs were achieved with an order quantity of 10,000 kg, which is also the optimal order quantity. Therefore, the order would be placed three times a year, which would reduce total annual costs by as much as €1,951. However, such procurement is associated with an expansion of storage capacity for flour, which means higher fixed costs related

TABLE 2 Purchase Prices of Ingredients

Ingredient	Unit cost (EUR)	Holding costs (EUR)
Yeast	1.70 /kg	1.70 x 0.2 = 0.34
Sugar	1.20 /kg	1.20 x 0.19 = 0.228
Salt	0.30 /kg	0.30 x 0.15 = 0.045

to the regular maintenance of silos. While the money would be tied up in stock for a longer period (120 days), this procurement policy would offer the bakery greater bargaining power, a better price per unit, and lower total annual costs. Given that flour has a shelf life of several years when properly stored, and that silos provide controlled storage conditions, such procurement would be suitable because it would not lead to flour waste.

The purchase prices for yeast, sugar, and salt are shown in Table 2.

Yeast is delivered to the bakery once a week, with each delivery being 32 kg. The annual consumption is 1,600 kg. The optimal order quantity is 320 kg. However, yeast is a perishable ingredient with a shelf life of 4 weeks. Purchasing quantities greater than $160 \times 0.04 \times 5 \times 4 = 128$ kg (3,200 yeast cubes) at once would therefore result in significant waste. The further the actual order size is from the optimal one, the higher the variable costs, which means the bakery should strive to place an order as close as possible to 320 kg. In this case, the bakery cannot order more than 128 kg at a time. We compared the variable costs at the optimal order quantity with the variable costs at the 128 kg quantity and found that reducing the order size by 60% increases annual variable costs by €48.96 (or 45%).

$$\frac{VC}{108.8} = \frac{1}{2} \times \left[\frac{320}{128} + \frac{128}{320} \right] = €157.76\ p.a.$$

The annual savings in this case still amount to €527.34.

Currently, the bakery places orders of 46 kg of salt at a time, which costs them €310.69 annually. The annual consumption of salt is 550 kg. Given that the unit cost and, consequently, the holding cost of salt are relatively low, it makes sense to place only one order per year. This would reduce the total annual procurement costs for salt by €128.49. Salt is a long-lasting ingredient. Therefore, from the perspective of quality deterioration or spoilage, this purchasing policy would not pose a problem.

The bakery orders sugar on a monthly basis, which means that they place orders of 55 kg. The annual consumption is 660 kg. This purchasing policy costs the bakery €898.59 annually. The EOQ model suggests an optimal order quantity of 220 kg. This would result in placing orders three times a year, which leads to an annual savings of €56.43.

Bakery 2

Bakery 2 is a modern artisanal sourdough bakery. Daily, they offer between 20 to 30 bakery products. The biggest challenge in inventory management is determining the optimal stock level for finished products each day. To determine the optimal inventory level, they primarily rely on observing customer purchasing habits. Unsold leftovers, which cannot be sold at a discount the next day, are frozen and reserved for internal use. White and mixed bread are turned into breadcrumbs and used in bread doughs for catering while the rest is used as feed for their chickens. The bread is prepared using a lengthy process that can take up to 24 hours. As they say, making sourdough is a process that does not allow for shortcuts. In the research, we used the Newsvendor model to solve the problem of daily determining the optimal inventory level for finished products, using wholemeal bread as an example. The demand for wholemeal bread is uncertain, and unsold leftovers lose their value after a day. If the bakery prepares too little bread, it results in a loss of sales (opportunity cost). Table 3 shows the predicted and actual daily demand for the ten best-selling products of Bakery 2 on March 13, 2024.

In forecasting demand for the next day, the bakery used the same method for all listed products, i.e. transferring the actual demand data

TABLE 3 A/F Ratio

Product Description	Actual Demand	Forecast	A/F ratio	Rank	Percentile/Rank divided by total number of products (10)
Seasonal bread	4	8	0.50	1	10
Sweetbox	3	5	0.60	2	20
Bread ‘Model’	11	16	0.69	3	30
Dark wholemeal bread	42	45	0.93	4	40
Bread Tartin	72	72	1.00	5	50
Baguette	16	15	1.06	6	60
Apple nest	13	12	1.08	7	70
Apricot bun	14	12	1.17	8	80
Cinnamon roll	12	10	1.20	9	90
Bun with chocolate and raspberries	12	9	1.33	10	100

TABLE 4 Discrete Distribution Function for Wholemeal Bread Using Past A/F Ratios.

A/F ratio	Q	F(Q)
0.5	21	0.1
0.6	25	0.2
0.6875	29	0.3
0.9333	39	0.4
1	42	0.5
1.0666	45	0.6
1.0833	46	0.7
1.1666	49	0.8
1.2	50	0.9
1.3333	56	1

from the previous day to the following day. The bakery predicted that the demand for wholemeal bread on March 14, 2024, would be the same as the previous day, i.e. 42 loaves. Upon reviewing past data, we found that the actual demand for several products on March 13, 2024, was either higher or lower than forecast. For all data points, we calculated the *A/F* ratio (*Actual Demand/Forecast*). Using these ratios, we measured the relative forecast errors for all products on March 13, 2024. We assumed that the forecast accuracy for wholemeal bread for the following day would be comparable. Therefore, for each A/F ratio, we could determine the corresponding level of demand (*Actual Demand* = *A/F ratio* × *Forecast*) for wholemeal bread and the probability of such or lower demand occurring (see Table 4).

We obtained a discrete probability distribution, which reflected the bakery's past forecasting accuracy but only predicted a limited number of possible outcomes. As an alternative to this probability distribution, we used a normal distribution. The randomness of actual demand is directly related to the randomness of the A/F ratio, as the forecast itself is not random. Therefore, the following applies:

$$\mu\ (\text{expected actual demand}) = \text{Expected } \frac{A}{F} \text{ratio } \times \text{Forecast.}$$

$$\sigma = \text{std.} \frac{A}{F} \times \text{Forecast.}$$

The standard deviation of our probability distribution was 12, and the mean value was 40.

We also defined the cost of stockouts (*Underage cost/Cu*), which is also the cost of lost opportunity, equal to the profit generated from selling one loaf of wholemeal bread (*selling price -purchase cost*), and the cost of excess inventory (*Overage cost/Co*), which is equal to the loss incurred from selling a loaf of bread at its salvage value (*purchase cost -salvage value*). The following applied to wholemeal bread:

- Selling price = €3.50/loaf.
- Purchase cost = €1.93/loaf.
- Salvage value (-50%) = €1.75/loaf.
- Co = €1.57.
- Cu = €0.18.

The bakery planned to produce $Q = 42$ units of the product. Within the marginal analysis, the question arose whether it should increase the quantity to $(Q + 1)$. The additional unit could potentially bring extra profit if the unit was sold.

$$\begin{aligned} \textit{Expected profit} &= Cu \times P\,(\textit{demand} > Q) \\ &= Cu \times (1 - P(\textit{demand} \leq Q)) \\ &= Cu\,(1 - F(Q)). \end{aligned}$$

$$\begin{aligned} \textit{Expected loss} &= Co \text{ x } P(\textit{demand} \leq Q) \\ &= Co \text{ x } F(Q). \end{aligned}$$

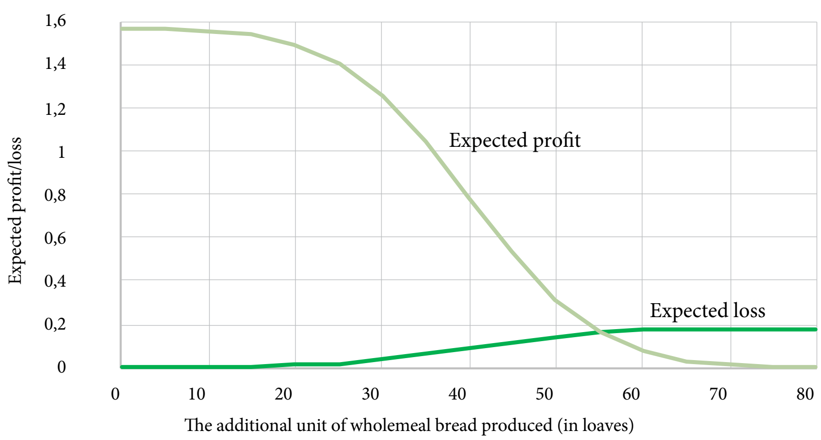

FIGURE 3 Expected Profit and Loss of an Additional Unit of Wholemeal Bread

When the produced quantity of wholemeal bread is very small, the probability of selling the additional unit is very high, $P\,(demand > Q) \cong 1$. Therefore, the expected profit is approximately €1.57. At the same time, the probability of not selling the additional unit approaches 0. As the produced quantity Q increases, the expected profit from the additional unit decreases while the expected loss increases. At a certain quantity, the expected loss exceeds the expected profit, and increasing the quantity Q becomes no longer profitable (see Figure 3).

We wanted to maximize profit at the optimal production quantity where the following holds:

$$Cu\ (1 - F(Q) = Co \times F(Q).$$

$$Cu - CuF(Q) = Co\ F(Q).$$

$$F(Q) = \frac{Cu}{Cu + Co}$$

$$Q = F^{-1}\left(\frac{Cu}{Cu + Co}\right).$$

$$\left(\frac{Cu}{Cu + Co}\right)$$

is called the *critical ratio*. At the optimal quantity Q, the following holds:

$$P\ (demand \leq Q) = \frac{Cu}{Cu + Co}$$

The critical ratio in our case was 0.8971. In the bakery, they would need to produce the quantity Q of wholemeal bread so that the probability that the demand for it is equal to or less than Q is 89.71%. This quantity was obtained using the MS Excel function NORMINV (0.8971,40,12). Alternatively, we could have found the variable z in the table of the standard normal distribution where the probability that the standardized normal variable z is less than or equal to a certain value is equal to the critical ratio. For the calculation, we would use the following formula: $Q = \mu + z\sigma$. We found that the bakery would need to produce $Q = F^{-1}\ (0.8971) = 55.18$ loaves $\cong$ 55 loaves of wholemeal bread on March 14, 2024. Using the loss function, we calculated the lost sales at Q = 55 using the equation ELS (*Expected lost sales*)$=\sigma \times L(z)$ where σ is a standard deviation and

$L(z)$ is the loss function. In our case demand was normally distributed, so we used the $L(z)$ table for the calculation. Alternatively, we could also have used the following Excel formula:

$$L(z) = Normdist\,(z, 0, 1, 0) - z \times (1 - Normsdist(z)).$$

The standardized normal variable z, which corresponds to the selected quantity, in our case Q = 55, was calculated using the following formula:

$$z = (Q - \mu)/\sigma = (55.182 - 40)/12 = 1.265$$

$$L(1.265) = Normdist\,(1.265;0;1;0) - 1.265 \times (1 - Normsdist(1.265)) \\ = 0.04902.$$

$$\sigma \times L(z) = 12 \times 0.\,04902 = 0.58824 \cong 1.$$

The expected lost sales were 0.58824, which means that the bakery can expect a loss of 1 unit of demand with the production of 55 loaves. Each unit of demand either results in a sale or represents a lost sale. The expected demand is the mean value of the demand distribution (μ), so the following holds:

$$Expected\ sales = \mu - Expected\ lost\ sales.$$

We estimated the expected sales in the case where the bakery produces 55 loaves of wholemeal bread, and the demand forecast follows a normal distribution. In this case, the expected lost sales amounted to 1 unit, and the expected sales were 40 − 1 = 39 units.

The expected leftover inventory is the average of all the values that the remaining stock can take. Each loaf of bread produced can either be sold or remain at the end of the day. Therefore, the following equation holds:

$$Expected\ sales + Expected\ leftover\ inventory = Q.$$

If the demand forecast is normally distributed and 55 loaves of bread are produced, the expected remaining stock is 55-39=16 units.

For each unit sold, the bakery earns the difference between theselling price and the purchase cost. For each unit that is not sold, it loses the difference between the purchase cost and the salvage value. The expected profit is calculated using the following formula:

$$Expected\ profit = \begin{bmatrix} (Selling\ price\ \text{-}\ purchase\ \cos t) \\ \times Expected\ sales \end{bmatrix} - \begin{bmatrix} (Purchase\ \cos t\ \text{-}\ Salvage\ value) \\ \times Expected\ leftover\ inventory \end{bmatrix}.$$

If the demand forecast is normally distributed and 55 loaves of wholemeal bread are produced, the expected profit is maximized and amounts to (1.57 × x 39) – (0.18 × 16)=€58.35.

SENSITIVITY ANALYSIS

To evaluate the robustness of inventory decisions, we conducted a sensitivity analysis on both the Economic Order Quantity (EOQ) and Newsvendor models. This analysis helps to understand how variations in key parameters affect overall performance and cost. The EOQ Model was tested under several conditions, including increased demand and higher holding costs. In the base case (yeast demand), the EOQ was 369.42 kg, leading to a total annual cost of 2,845.60€. When demand increased by 10%, the EOQ rose to 387.45 kg, with an associated annual cost of 3,124€. Conversely, when holding costs increased by 15%, the EOQ slightly decreased to 361.3 kg, while the annual cost rose marginally to 2,854.85€. These results (for yeast, salt and sugar) highlight that EOQ is sensitive to both demand and holding costs, though the total cost impact remains moderate, suggesting the model's relative stability in practical applications.

For the Newsvendor model, we evaluated performance across similar demand scenarios. In the base case, with a bake quantity of 45 loaves, expected sales were approximately 36.95 loaves, resulting in 3.05 loaves of lost sales and 8.05 loaves in leftover inventory. This yielded an expected

TABLE 5 EOQ Model Sensitivity Analysis

Scenario	EOQ (kg)	Total Annual Cost (€)
Base case - YEAST	369.42	2,845.60
Demand +10%	387.45	3,124.00
Holding costs +15%	361.29	2,854.85
Base case - SALT	550.00	189.20
Demand +10%	576.84	206.88
Holding costs +15%	537.91	190.98
Base case - SUGAR	220.00	842.16
Demand +10%	230.74	923.80
Holding costs +15%	215.16	845.85

TABLE 6 Sensitivity of Expected Profit to Quantity Baked (Newsvendor model)

Quantity baked (in loaves)	Exp. sales	Exp. lost sales	Exp. leftover inv.	Exp. profit (EUR)
45	36.95	3.05	8.05	56.56
55	39.41	0.59	15.59	59.07
60	39.76	0.24	20.24	58.78

TABLE 7 Effect of Demand Mean Variation on Optimal Production (Newsvendor model)

Scenario	Mean	Std. dev.	Optimal Q
Base case	40	12	55
Higher demand	45	12	60
Lower demand	35	12	50

TABLE 8 Impact of Demand Variability on Inventory Decisions (Newsvendor model)

Scenario	Mean	Std. dev.	Optimal Q
Base case	40	12	55
Higher demand	40	15	59
Lower demand	40	10	53

profit of €56.56. Increasing demand to an optimal 55 loaves improved sales to 39.41 and profit to €59.07, with slightly more leftovers. A further increase in baked quantity to 60 loaves maintained high sales (39.76) but also increased leftovers (20.24), slightly reducing profit to €58.78 (see Table 6). Similarly, increasing demand variability while keeping the standard deviation constant (see Table 7), or increasing the standard deviation while holding the demand mean constant (see Table 8), both led to higher production quantities – in the first case due to increased demand, and in the second due to greater uncertainty.

Overall, the sensitivity analysis confirms that both models react predictably to parameter changes, reinforcing their usefulness for inventory planning.

Conclusion and Policy Implications

Below are the key findings based on the analysis of relevant literature and the conducted research.

In connection with the first goal, we find that Bakery 1 primarily faces the issue of managing the stock turnover of raw materials while Bakery 2 struggles with determining the optimal stock quantities of finished products daily.

In connection with the second goal of the research, we find that Bakery 1 prepares the demand forecast based on past trends. Similarly, Bakery 2 places a strong emphasis on observing consumer purchasing habits when forecasting demand. In both bakeries, we highlight the lack of systematic recording of actual daily demand, demand forecasts, and forecast errors, which serve to estimate the standard deviation of demand. Bakery management should not forget that, due to a lack of stock, actual demand may exceed actual sales. In cases where it is not possible to monitor actual demand after stock shortages occur, it is necessary to estimate actual demand reasonably. In the case of Bakery 2, we found that the data on actual demand for an item should not simply be transferred and used as a forecast for the following day. We also need a forecast of how demand will vary around the forecast. The uncertainty is captured by the standard deviation of demand. While it is impossible to align supply and demand fully, since the quantity of bread to be offered must be decided well before the start of sales and demand is uncertain, it is possible to make a decision that balances the cost of overproduction and the cost of insufficient production. Uncertainty should not lead to ad hoc decision-making.

In connection with the third goal, we find that surpluses occur daily. The products that Bakery 1 cannot sell are redistributed for animal feed while Bakery 2 freezes them for internal use, and the surplus is used as feed for domestic chickens. White bread in both bakeries is ground into breadcrumbs, and Bakery 2 also uses white and mixed bread for breadcrumbs which are included in catering and thus add value to the bread.

In connection with the final goal, we highlighted the usefulness of the EOQ and Newsvendor models in solving the problems identified by the bakeries during the interview. In Bakery 1, perishable ingredients are purchased 1–2 times a week, and white and whole-wheat flour every month and a half, while other ingredients are purchased monthly. Based on our research and the application of the EOQ model, we would recommend to the bakery management to order dry ingredients – flour, salt, and sugar – less frequently but in larger quantities than they currently do, because this is much more cost-effective for the bakery, and due to the long shelf life of the ingredients, it does not result in waste. The bakery would, thus, place flour orders of 10,000 kg, which is associated with expanding storage capacity, salt orders of 550 kg, and sugar orders of 220 kg. The situation is different for yeast, where the EOQ model predicts a larger purchase quantity than they currently order. However, this would lead to significant waste due to the shorter shelf life of yeast. To avoid waste and minimize annual procurement costs, it makes sense to purchase exactly 128 kg (no more and no less) of yeast at a time. By implementing optimal procurement of white and whole-wheat flour for bread, the bakery would save as much as €1,951 (18.35% compared to the previous state), and by purchasing yeast, sugar, and salt for all types of bread, they would save €712.26 (about 15% compared to the previous state) annually. Based on the results of our research, *we can confirm H1* that Bakery 1 could reduce total annual procurement costs by more than 15% through more efficient inventory management without causing spoilage or waste of raw materials.

These outcomes align closely with findings in prior studies. For example, Wardana et al. (2025), in a case study of Chopfee Coffee Shop, reported a 71.7% inventory cost reduction following the implementation of EOQ for coffee beans and sugar. While the magnitude of cost savings in our study is smaller, the application is similarly effective, particularly considering the more modest scale and input variability of the bakery studied here. Similarly, Mulyana and Zuliana (2019) applied EOQ in a small-medium enterprise Ananda Bakery and observed improved inventory control and reduced stockouts. As in that study, our EOQ approach includes a focus on raw material ordering consistency and annual cost reduction, although safety stock was not incorporated due to relatively stable demand in Bakery 1.

In the case of Bakery 2, we found that the quantity produced, which maximizes profit, is usually not equal to the expected demand. If the cost of stockouts is greater than the cost of excess inventory, as is the case with wholemeal bread, the quantity that maximizes profit is greater than the expected demand. The critical ratio is, in fact, greater than 0.5. A loaf that remains costs the bakery much less than not having a loaf available if there is demand for it. Although the goal of our research was to minimize the mismatch between supply and demand in the case of wholemeal bread and thus minimize bread waste, the model suggests that explicit costs should not outweigh opportunity costs if the bakery wants to maximize profit. The remaining inventory at the end of the day is actual, while lost sales are an opportunity cost of the mismatch between supply and demand. Focusing on minimizing explicit costs in Bakery 2 results in producing less wholemeal bread than they should to maximize profit. To maximize profit, they should have produced 55 loaves of wholemeal bread on the selected day, March 14th, which is 13 more loaves than they actually produced that day.

This insight closely mirrors the findings of de Muinck Keizer et al. (2024), where a stochastic Newsvendor model was used to optimize stocking strategy for cakes in small bakeries under demand uncertainty. Their model extended the classic Newsvendor framework by accounting for customer substitution behaviour and demand forecasting. While our approach did not include substitution effects, it reinforced the importance of accounting for lost sales and missed profit opportunities due to conservative production estimates. If the bakery aims to achieve the goal of maximizing profit while also minimizing waste, it must effectively manage the expected remaining bread stock, which in this case is relatively high due to the reasons mentioned before. For products that are intended for animal feed, where the salvage value is much lower (80–90% lower than the selling price) and the inequality Co > Cu holds, the Newsvendor model suggests producing a smaller quantity of the product than the expected demand, which leads to a smaller expected remaining stock and waste. We *can also confirm H2* that the goal of minimizing food waste in Bakery 2 is not necessarily compatible with the goal of maximizing profit.

Understanding and applying the EOQ and Newsvendor models, together with practices that create added value (e.g. circular economy), could enable the management of these and other similar companies to better plan production and procurement, both in terms of cost management and subsequent profit maximization, as well as minimizing waste. Although the study was conducted in only two small Slovenian bakeries, the findings can be applied to other bakeries in several meaningful ways. The core inventory management challenges – such as unpredictable demand, limited storage, and the perishability of products – are common to many bakeries, regardless of size. The models used in this research (EOQ and Newsvendor) are flexible and can be adapted to any bakery that has access to basic operational data like daily demand, production costs, and spoilage rates. Other bakeries can apply the same methodology by collecting similar input data and using the models to optimize their ordering and production decisions. While exact figures may differ depending on bakery size, product range, or supplier relationships, the approach provides a practical decision-making framework that improves efficiency and reduces waste. In this way, the results may serve as a guide for other bakeries aiming to improve inventory practices, especially those with similar characteristics to the case bakeries.

In practice the application of the Newsvendor model and EOQ model can be time-consuming and challenging for small bakery owners, especially due to the need for accurate demand forecasting and probabilistic analysis. Without access to advanced tools or technical expertise, manually calculating optimal order quantities may be impractical. However, user-friendly software or mobile apps tailored for small businesses could simplify this process. By integrating sales history, local demand patterns, and built-in statistical tools, such applications can automate the Newsvendor and EOQ logic and provide real-time information on either the optimal order quantity of raw materials or the optimal quantity of the final product to be produced – helping bakery owners make smarter daily production decisions with minimal effort.

Based on our study, the following actionable recommendations are proposed for practitioners and policymakers. Data-driven inventory planning should be implemented through the use of historical sales data to estimate demand. EOQ should be applied for stable inputs, while the Newsvendor model should be used for perishable goods with uncertain demand. Production should be adjusted dynamically based on demand trends through monitoring demand shifts and use of updated demand estimates to recalculate Newsvendor quantities weekly or even daily. Quantity discounts should be applied strategically. When purchasing large quantities to benefit from price reductions, they should evaluate holding costs carefully to avoid unnecessary waste. Digital tools for forecasting might also be introduced. Practitioners might adopt simple forecasting software integrated with sales data to make EOQ and Newsvendor decisions semi-automated and user-friendly for non-specialists.

In addition to operational improvements at the bakery level, broader support from policymakers and local authorities is essential to scale the benefits of inventory optimization and food waste reduction across the sector. They can support training programmes on inventory optimization, offer tax benefits or grants to bakeries that adopt quantifiable food waste reduction strategies, or encourage bakeries to track and share food waste metrics, creating benchmarks and best practices within the local food ecosystem.

Besides optimal inventory management, further studies on how bakeries can reduce waste might focus also on other potential waste reduction strategies like circular economy principles integration such as repurposing unsold products into new offerings or partnering with local farms for composting organic waste. Dynamic pricing models could be implemented to discount items nearing the end of their freshness window, encouraging timely sales. Donation programmes to local shelters or food banks can help reduce surplus without loss. Additionally, using real-time sales tracking to adjust production dynamically, and adopting smaller batch baking practices throughout the day (just-in-time baking), can help minimize overproduction. Finally, investing in employee training on portion control, storage techniques, and efficient ingredient usage can also significantly cut down on internal waste.

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Abstracts in Slovene

Vključevanje raziskav o sreči v končne kazalnike družbene analize življenjskega cikla

Stefan Mann in Melf-Hinrich Ehlers

Končni kazalniki za analizo družbenega življenjskega cikla (S-LCA) so še vedno manj konsolidirani kot tisti za okoljsko LCA. Obstaja široko soglasje, da bi moralo biti človekovo blagostanje osrednji cilj družbene trajnosti in s tem tudi S-LCA. Kljub temu sta trenutno dve glavni podatkovni zbirki za S-LCA omejeni na množenje delovnih ur s kakovostnim ali tveganjsko prilagojenim faktorjem. Namen tega prispevka je oceniti skladnost med to tehnično pragmatičnostjo in dobro uveljavljenimi ugotovitvami raziskav o sreči. Analiza se začne z argumentom, da sta dokazljivost in posledičnost nujna kriterija za vsako uporabljeno spremenljivko. Nato je prikazano, da nekatere spremenljivke, kot je revščina, niso posledične, medtem ko enota delovnih ur ne izkazuje nobenih dokazov o povezavi s subjektivnim blagostanjem. Analiza zaključi, da bi bil preprost točkovni končni kazalnik primernejši za S-LCA kot trenutni kazalnik, ki temelji na urah.

Ključne besede: družbena trajnost, analiza življenjskega cikla, kazalniki, končni kazalnik
Klasifikacija JEL: P11
Managing Global Transitions 23 (3): 214–258

Optimizacija zalog kot orodje za zmanjšanje živilskih izgub in povečanje dobičkonosnosti: Študija primera malih pekarn v Sloveniji

Špela Lipnik in Žiga Čepar

Ta članek raziskuje vlogo upravljanja zalog pri zmanjševanju zavržkov hrane in izboljšanju gospodarske uspešnosti v izbranih slovenskih pekarnah ter tako prispeva k učinkovitejšemu, okoljsko odgovornemu in trajnostnemu gospodarstvu. Z uporabo polstrukturiranih intervjujev s ključnim osebjem pekarn ter poglobljeno analizo poslovne dokumentacije študija uporablja model ekonomske količine naročila (EOQ) in model Newsvendor za preverjanje naslednjih dveh hipotez: (H1) izboljšanje upravljanja zalog v Pekarni 1 lahko zmanjša skupne letne stroške nabave za več kot 15 % brez povzročanja kvarjenja ali zavržkov surovin, in (H2) zmanjševanje zavržkov hrane v Pekarni 2 ni nujno usklajeno z maksimiranjem dobička. Ugotovitve potrjujejo, da uporaba teh modelov lahko izboljša načrtovanje proizvodnje in nabave ter pokažejo, da sta tako zniževanje stroškov kot zmanjševanje zavržkov dosegljiva, vendar nista vedno popolnoma usklajena. Študija poudarja pomen strateškega upravljanja zalog za uravnoteženje finančnih in okoljskih ciljev v malih pekarnah.

Ključne besede: modeli upravljanja zalog EOQ in Newsvendor, optimizacija zalog, zmanjševanje zavržkov hrane, trajnostno gospodarstvo, Slovenija
Klasifikacija JEL*:* Q010, Q530
Managing Global Transitions 23 (3): 259–294

Priložnosti za indijske ženske pri priložnostnih delih brez uporabe digitalnih platform: Pomen poklicnega usposabljanja

Sayantani Santra in Amit Kundu

Fleksibilni delovni čas lahko ponudi boljšo možnost za indijske ženske, ki vstopajo na trg dela. To je mogoče doseči z opravljanjem priložnostnih del brez odvisnosti od digitalnih platform, saj ima veliko posameznikov omejen dostop do tehnologije. Priložnostni delavci in samozaposleni so obravnavani kot delavci na podlagi priložnostnih pogodb (gig workers), ki lahko svoje delo opravljajo brez uporabe digitalnih platform. Probit model identificira dejavnike, ki lahko povečajo verjetnost opravljanja takšnih priložnostnih del brez uporabe digitalne platforme za indijske ženske. Z uporabo bivariantnega Probit regresijskega modela, ki temelji na podatkih Periodične ankete o delovni sili za leto 2022–23, in ob upoštevanju endogenosti članek pokaže, da tako formalno kot neformalno poklicno usposabljanje pozitivno vplivata na udeležbo žensk pri opravljanju priložnostnih del brez uporabe digitalnih platform. Vendar pa je vpliv neformalnega usposabljanja izrazitejši.

Ključne besede: priložnostno delo (gig job), samozaposleni delavec, priložnostni nadomestni delavec, neplačano gospodinjsko delo, formalno poklicno usposabljanje, bivariantna Probit regresija
Klasifikacija JEL*:* C51, C87, J44, J78, R20
Managing Global Transitions 23 (3): 295–326

Je okoljska Kuznetsova krivulja še aktualna v današnjem času? – Analiza onesnaženosti zraka v kitajskih mestih

Jun Wang, Shinah Park in Gulsah Akar

Ta študija je raziskovala prisotnost odnosov, podobnih okoljski Kuznetsovi krivulji (EKC), med različnimi socioekonomskimi spremenljivkami in kazalniki onesnaženosti zraka v 151 kitajskih mestih, ana-