**Czech University of Life Sciences Prague**

**Faculty of Economics and Management**

**Department of Systems Engineering**

# Bachelor Thesis

## A comprehensive study of inventory processes in a sushi restaurant

**Vitaly Karpov**

# CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

# BACHELOR THESIS ASSIGNMENT

Vitaly Karpov

Economics and Management

Thesis title

**A comprehensive study of inventory processes in a sushi restaurant**

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**Objectives of thesis**

The main goal of this bachelor thesis is to understand and compare the existing inventory management practices in a chosen sushi restaurant, in aim to identify opportunities for operational efficiency, cost reduction and providing practical recommendations for improvement.

**Methodology**

A. Understanding Inventory Management: To develop a deep understanding of inventory management principles, concepts, and best practices in the context of a sushi restaurant. This involves researching various inventory control methods and understanding how they apply to perishable food items like sushi.

B. Analyzing Current Processes: To assess the existing inventory management processes in the selected sushi restaurant. This involves observations to gather relevant data on how the restaurant currently manages its inventory.

C. Cost Analysis: Calculating and analyzing the costs associated with inventory, including holding costs, ordering costs, and stockout costs, to determine the financial impact of the restaurant's inventory management practices. This also involves quantifying potential cost savings and improved operational efficiency against the costs associated with implementing new processes.

D. Proposing Process Improvements: Developing recommendations for process improvements in the restaurant's inventory management, with a focus on optimizing inventory levels and improving overall efficiency.

**The proposed extent of the thesis**

40

**Keywords**

Inventory models; inventory control methods; order; stochastic demand; optimal order size; unsatisfied demand; storing cost.

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**Recommended information sources**

DÖMEOVÁ, Ludmila; BERÁNKOVÁ, Martina; ČESKÁ ZEMĚDĚLSKÁ UNIVERZITA V PRAZE. KATEDRA OPERAČNÍ A SYSTÉMOVÉ ANALÝZY. *Modely řízení zásob I.* Praha: Česká zemědělská univerzita, Provozně ekonomická fakulta ve vydavatelství Credit, 2004. ISBN 80-213-1140-1.

Karlin, S., and H. Scarf. 1958. "Inventory Models and Related Stochastic Processes." Studies in the Mathematical Theory of Inventory and Production 1: 319-336

SCHREIBFEDER, Jon. *Achieving effective Inventory management.* Copell: Effective Inventory Management, 2008. ISBN 9780967820057.

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**Supervising department**

Department of Systems Engineering

| Electronic approval: 8. 3. 2024 | Electronic approval: 12. 3. 2024 |
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| **doc. Ing. Tomáš Šubrt, Ph.D.** | **doc. Ing. Tomáš Šubrt, Ph.D.** |
| Head of department | Dean |

Prague on 12. 03. 2024

**Declaration**

I declare that I have worked on my bachelor thesis titled "A comprehensive study of inventory processes in a sushi restaurant" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break any copyrights.

In Prague on 13.03.2024 ____________________________

**Acknowledgement**

I would like to thank Ing. Robert Hlavaty, Ph.D. for mentorship, invested time and motivation to work. Additionally, I would like to thank my family for their belief in my goals and me. Most heartfelt thanks to Imperial Sushi s.r.o. for cooperation and data presentation.

# A comprehensive study of inventory processes in a sushi restaurant

**Abstract**

This thesis focuses on optimizing the inventory process of a specific product in a sushi restaurant Imperial Sushi s.r.o. It analyses current practices against best possible practices from the theoretical part to identify opportunities for improved operational efficiency, reduced inventory holding costs, and implementation of practical solutions. The research employs a multi-pronged approach: reviewing relevant academic literature, analyzing restaurant's data, applying appropriate models (including ABC analysis), and calculating optimal inventory costs.

Ultimately, the aim is to deliver actionable recommendations that enhance the restaurant's inventory management, leading to increased efficiency and cost-effectiveness.

**Keywords:** inventory models; deterministic demand; stochastic demand; optimal order size; optimal reordering level; holding cost; acquisition cost; total cost.

# Podrobná studie procesu řízení zásob v sushi restauraci


**Abstrakt**

Tato diplomová práce se zaměřuje na optimalizaci procesu řízení zásob v sushi restauraci Imperial Sushi s.r.o. Analyzuje současné postupy oproti nejlepším možným postupům z teoretické části s cílem identifikovat příležitosti pro zlepšení provozní efektivity, snížení nákladů na držení zásob a implementaci praktických řešení. Výzkum využívá vícestupňový přístup: rešerši relevantní odborné literatury, analýzu dat restaurace, aplikaci vhodných modelů (včetně ABC analýzy) a výpočet optimálních nákladů na zásoby.

V konečném důsledku je cílem poskytnout realizovatelná doporučení, která zlepší řízení zásob v restauraci, což povede ke zvýšení efektivity a hospodárnosti.



**Klíčová slova:** modely řízení zásob; deterministická poptávka; stochastická poptávka; optimální velikost objednávky; optimální úroveň objednávky; náklady na skladování; pořizovací náklady; celkové náklady.

# Table of content

# 1 Introduction

The food industry has changed a lot through the last ten years. People have met and tasted a huge amount of different new cuisines and meals. Sushi has doubtlessly won the podium place in hearts and bellies of customers not only in the motherland of the product, but also all over the world. A simple combination of a few ingredients makes enterprising businessman open new and new restaurants practically every month in order to conquer new customers and of course their money.

The simplest way to win in the race for customers is to present the freshest products with a combination of knowledge of how to mix and serve them well. “It is very simple!” - someone may say. However, there is a great job done behind the scenes. There is always a good manager at the head of each successful sushi restaurant. That manager is responsible for the freshness of each slice of fish, single grain of rice and every piece of cucumber put in a sushi roll. Behind the scenes of success lies a complex web of inventory management processes that ensure the seamless operation of these establishments.

The purpose of this Bachelor Thesis is to understand that scenes of inventory process in the context of a selected company – sushi restaurant “Imperial Sushi”, based in Prague. Studying the theoretical background of the inventory process in the context of the sushi restaurant, analyzing the key variables like demand, storing cost and the acquisition cost, it will be figured out the best inventory method for the company.

Certainly, after the practical part of the work some improvements will be proposed. Once the total inventory costs have been calculated and analyzed, potential savings and operational efficiencies will be quantified against current costs.

The choice of the topic of the thesis was conditioned by its relevance, practical and scientific significance. The study of the works of the following authors (Muriana, 2020), (Theodorou, et al., 2023), (Ortega, et al., 2024) in the same area confirms the relevance of the problem and the need for further research. Such a significant number of relatively recent works of the mentioned authors suggests that each case has its own unique solution, which is to be revealed during this work.

# 2 Objectives and Methodology

## 2.1 Objectives

The main objective of the thesis is to propose an optimization in the inventory process related to the selected product by comparing the existing inventory management practices in a chosen sushi restaurant, in aim to identify opportunities for operational efficiency, cost reduction and providing practical recommendations for improvement.

## 2.2 Methodology

Various methodological procedures are employed in this thesis throughout its theoretical and practical part. The first part will be a theoretical part, where simple processes of inventory theory and management will be described and analyzed.

The opening section of the theoretical part defines key concepts of the topic exploring the principals of inventory theory as a part of a bigger discipline - operational research. The initial methodological step involves studying relevant literature to gain deep knowledge of inventory theory's complexities, connected with the nature of demand. To understand this term, it is necessary to describe the necessary variables that will be encountered in the theoretical and practical parts.

Further the selected inventory control models are described by relevant literature. The models included in this thesis: basic EOQ model, EOQ models with quantity discounts, Just-in-Time model and models with stochastic demand.

The practical section of this thesis digs into real-world application by collaborating with a chosen company experience and data. One item from the restaurant's daily use was selected by using the ABC analysis applying the statistics provided by the firm for the previous year.  Afterwards, using selected and mentioned models, the optimal values of order size, reordering level and quantity discount simulation will be calculated.

Combining the knowledge from the first theoretical part with practical findings, the study makes up a conclusion of recommendations specifically for the company Imperial Sushi s.r.o.

# 3 Theoretical part

## 3.1 Operational Research

### 3.1.1 Definition and history

Operational Research (OR), also known as Operations Research, is a field of study that uses mathematical and analytical methods to make better decisions and solve complex problems in organizations. It involves the application of quantitative techniques, modelling and analysis to conduct decision-making processes related to the operation and management of systems (Taha, 2017).

After the war, the successful idea of efficient and productive usage of the resources penetrated into civilian lives.

### 3.1.2 Key phases of OR

There are six key phases of the Operational Research (Kothari, 2009):

- *Formulating the problem*: The core of any Operations Research analysis is the careful definition of the problem. This involves accurately identifying, clarifying, and expressing the approach for measuring the fundamental components of a mathematical model that reflects the situation. All measurable factors that affect the system's operation are transformed into mathematical expressions.
- *Constructing the model*: The next step involves creating the model itself. This requires formulating mathematical expressions that capture the complex relationships among all variables and parameters that affect the system. A key element is the introduction of an “objective function” that quantifies the effectiveness of the system. The problem-solving model's idea lies in the interaction between the objective function and constraints.
- *Deriving the solution*: After constructing the model, the next stage of Operations Research study is to find the optimal solution. This involves identifying the most suitable values for the controllable variables. The objective is to satisfy the equations within the model while observing the system's constraints and relationships, and simultaneously maximizing profit, minimizing cost, or achieving another desired outcome.

- *Testing the validity*: After finding the optimal solution within the model, the real test begins. The solution values are compared against actual observations to assess the model's validity. A reliable model produces accurate predictions of the system's performance. The model must be updated based on observed data if unexpected events occur. This iterative process continues until the model accurately reflects the system's behavior. Validation ensures that the model is not only a good equation, but also a practical tool for making better decisions in the real world.
- *Controlling the solution*: This step of an OR study emphasizes the critical role of continuous control through information feedback, beyond simply identifying an optimal solution. Significant changes in the variables or the system environment also require adjustments to the previously determined solution.
- *Implementing the results*: The final step of an operations research (OR) study is implementing the results. OR aims not only to produce reports, but also to improve the performance of systems, so the research findings, if accepted, must be implemented by decision-makers. This step is where the ultimate test and evaluation of the research is conducted, providing the researcher with the greatest opportunity for learning.

While the steps outlined in an Operations Research (OR) study typically follow a sequential order, it is essential to remember that this process is dynamic and iterative. It is highly likely that these phases and steps will overlap and interact throughout the study.

In other words, each phase is not necessarily completed in isolation before moving on to the next. Instead, phases can run concurrently, with findings from later stages informing and refining earlier work (Hillier & Lieberman, 2001). This ongoing interaction is well shown in the following chart:

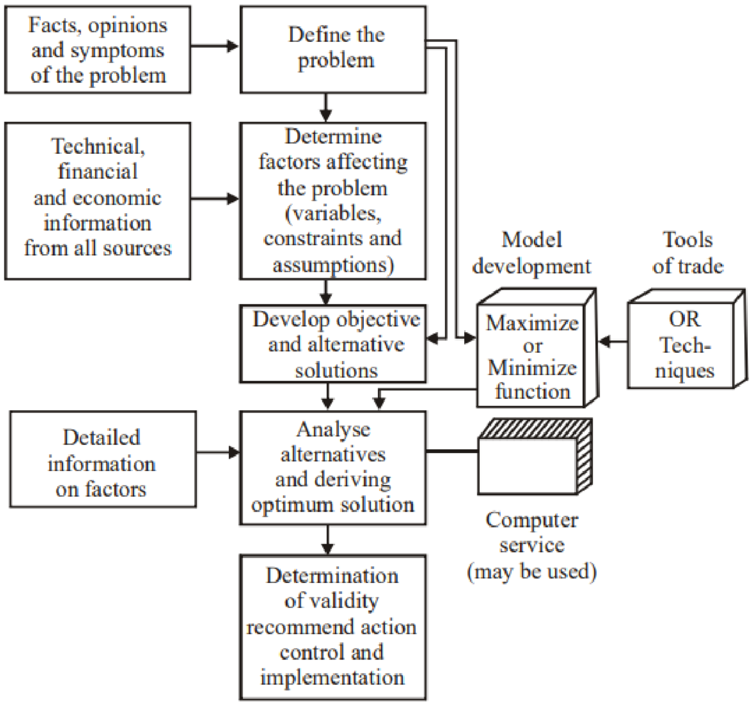


*Figure 1 – The flow chart of OR approach, source: (Kothari, 2009, p. 9)*

### 3.1.3 Classification of OR models

Operational Research (OR) represents a rich and powerful arsenal of tools and techniques for solving complex decision-making challenges. To effectively navigate this comprehensive portfolio, researchers have developed various classification frameworks. These frameworks serve a critical purpose, acting as a strategic roadmap for understanding the unique characteristics of different OR tools. These classifications allow managers to make informed choices and select the most appropriate technique for a given problem.

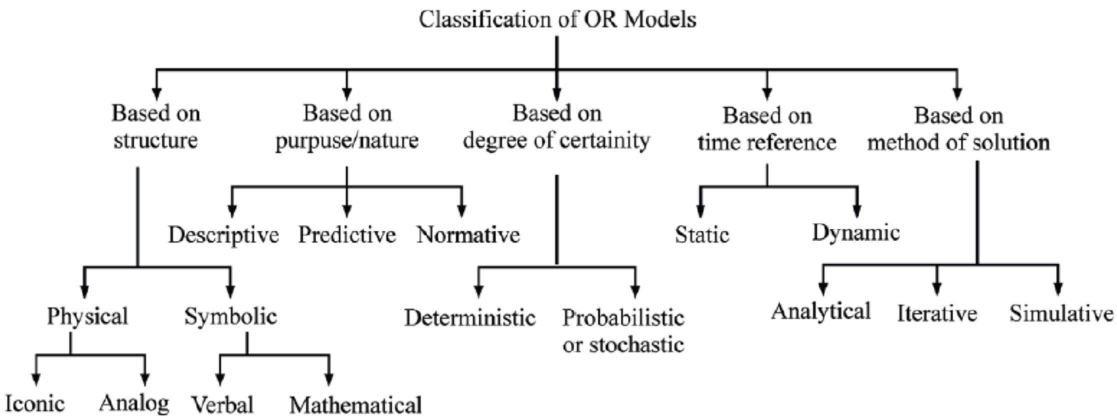


*Figure 2 – Classification of OR models, source: (Taha, 2017, p. 34)*

## 3.2 Types of stock

In the context of operational research and inventory management, "stocks" refer to the various types of items held in storage to meet future demand. These items can be categorized based on different criteria, with two common classifications (Schreibfeder, 2008):

- *By function*
- *By demand*

### 3.2.1 ABC analysis

Categorizing stocks by demand using an ABC analysis classification is an effective way of optimization of inventory management. This practice enables more efficient allocation of resources and attention. This results in more quality of inventory control, decreased costs, improved product availability.

Managing a large inventory can be challenging, particularly when dealing with items of varying value. While all items require some level of control, it is essential to prioritize those with higher costs (Teunteros, et al., 2010).

In certain businesses, a few expensive items may make up a significant portion of their total inventory value, while many other inexpensive items make up the remaining value. In such cases, a selective approach to inventory control is crucial.

The most efficient technique for this is ABC analysis (Mishra & Jaishankar, 2011). This method analyses how the total inventory value is distributed among individual items. It relies on the Pareto principle, also known as the 80/20 rule (Schreibfeder, 2008, p. 30), which states that a small percentage of items (often 20%) contribute to a large majority of the value (often 80%):

- *A-items (High Demand, High Value)*:

These are the most valuable and mostly vital items of the inventory, representing a small percentage (20%), but contributing to a large part (80%) of the sales.

As an example of this kind of item in a sushi restaurant is highly demanded fish, like salmon and tuna, for instance.

- *B-items (Moderate Demand, Moderate Value)*:

These groups of products represent a larger proportion of the inventory (30%) and contribute to a moderate portion of the sales (15%).

Examples: Less popular fish or seafood, like shrimps.

- *C-items (Low Demand, Low Value)*:

This group is the largest (50%) art of the inventory, but it contributes the least in the sales (5%).

Some rarely used goods such as tuna flakes, for example.

## 3.3 Basic variables

Inventory management deals with balancing inventory levels to meet customer demand while minimizing costs. Understanding which variables you can control and which you cannot is crucial for effective decision-making. Here is a table of most common variables met during this study. Further, each variable and even some others will be described separately in appropriate sub-groups for a deeper understanding.

All the variables are basically divided into two main groups: controlled and uncontrolled, according to whether the manager can directly influence them with his decisions, or they are under direct control. (Dömeová & Beránková, 2004, pp. 6-9)

| Variable title | Symbol | Example of a unit |
|---|---|---|
| *Order size* | $Q$ | *pcs, kg, l* |
| *Delivery cycle* | $t_c$ | *hour, day, month* |
| *Reorder level* | $R$ | *pcs, kg, l* |
| *Safety stock* | $w$ | *pcs, kg, l* |
| *Lead time* | $t_d$ | *hour, day, month* |
| *Unit storage cost* | $k_s$ | *Kč / unit* |
| *Fixed acquisition cost* | $k_o$ | *Kč / order* |
| *Cost of shortage* | $k_n$ | *Kč / unit of scarcity* |

*Table 1 – Overview of basic variables in inventory management, source: (Dömeová & Beránková, 2004, p. 8)*

### 3.3.1 Controlled variables

It is clear from the name of these variables, that the firm's manager is able to control them, i.e. increase or decrease if necessary. These variables are: (Dömeová & Beránková, 2004, p. 6)

- *Order size:* $Q$

The amount of inventory to order during the replenishment cycle. The size of delivery is equal to the order size and is given in pieces, tons, liters, etc.

- *Length of delivery cycle:* $t$

It is the total time needed from placing an order to its delivery to the warehouse or shop. The time between two subsequent orders is called the delivery cycle and is given mostly often in days. Replenishment may occur in different intervals; therefore, the delivery cycle may not always be constant.

- *Order level: R*

It is a quantity of the stock in the warehouse that lies between the maximum and minimum stocks level. The exact level depends on factors like average daily usage, lead time, and safety stock. Sometimes order level is also called "reorder point".

- *Safety stock:* $w$

This is the over stock held above the planned demand to handle with stockouts in case by high demand, lead time variations, or unexpected events. It is like an insurance policy for the inventory, making the company be sure it has enough in case of emergency.

### 3.3.2 Uncontrolled variables

Uncontrolled variables cannot be regulated by a manager in the inventory process. These variables are under the control of the company either. These variables are more often related to phenomena outside of the system (i.e. they come from outside as objective data). They are guesses at the way things will play out, things we can't exactly influence or predict (Dömeová & Beránková, 2004, p. 7). These variables are:

- *Total annual demand:* $D$

Total annual demand is the expected annual consumption of the chosen product. When the amount is not definitely known, it is usually used its estimation.

- *Lead time:* $t_d$

In inventory management, lead time refers to the duration between placing an order to restock inventory and receiving that order. The lead time directly influences the quantity of stock a company must maintain at any given moment. If the lead time is very short, it should not be concerned.

### 3.3.3 Cost variables

Uncontrollable variables also include cost variables. For each type of cost, it can be shown the difference between unit costs and total costs. So, it is more convenient to look at the cost through two different groups: unit cost variables and total cost variables (Dömeová & Beránková, 2004, pp. 7-8).

- *Unit cost variables:*

| *Title* | *Symbol* | *Description* |
|---|---|---|
| *Storage cost* | $k_s$ | *Generally, refers to the cost of storing one unit of an item for a specific period. A considerable part of these costs are losses from the spoilt goods.* |
| *Fixed acquisition cost* | $k_o$ | *They apply to a single order regardless of the number of items in the order. They may include shipping, handling, packaging costs, administration and communication.* |
| *Cost of shortage* | $k_n$ | *It refers to the financial loss incurred when you are unable to meet customer demand due to insufficient inventory.* |

*Table 2 – Overview of unit cost variables, source: (Dömeová & Beránková, 2004, pp. 7-8)*

- *Total cost variables:*

| Title | Symbol and formula | Description |
|---|---|---|
| *Total annual storage costs* | $c_s = \frac{Q}{2} * k_s$ | *Refers to the total costs accumulated for storing your inventory over a year.* |
| *Total annual fixed acquisition cost* | $c_o = \frac{D}{Q} * k_o$ | *Refers to total annual fixed cost and is equal to the fixed costs of all realized deliveries during the year.* |
| *Total annual cost of shortage* | $c_n$ | *The calculation is not that simple: usually the losses are calculated one-off. Depends on the size of the unsatisfied demand, not time.* |
| *Total annual costs* | $TC = c_s + c_o$ <br> *or* <br> $TC = \frac{Q}{2} * k_s + \frac{D}{Q} * k_o$ | *Are calculated as the sum of the total annual storage costs and total annual fixed acquisition costs.* |
| | $TC = c_s + c_o + c_n$ | *Assuming or allowing the condition shortage of stock, the annual total cost of shortage should be added.* |

*Table 3 – Overview of total cost variables, source: (Dömeová & Beránková, 2004, pp. 8-9)*

## 3.4 Inventory models

The problem of inventory control seems to be one of the most important in business management. There cannot be one perfect solution, as a rule. However, the eagerness of the management to solve the occurring task leads to the existence of a great variety of inventory models. (Sixta & Žižka, 2009, p. 71)

Inventory models can be classified by several key characteristics, for example, by lead time, production environment, by complexity of the order (Silver, 2008):

- *Deterministic models* – the exact requirements for purchased raw materials and semi-finished products are known in advance for the chosen period. Customer demand for the final product is also completely predictable for the same period.
- *Stochastic (or probabilistic) models* – demand levels can only be estimated with some degree of certainty.

There is also classification of the models according to the replenishment methods:

- *Static models* – stock is built up by a one-off supply.
- *Dynamic models* – stock is maintained in stock for a long time and is replenished by repeated deliveries.

### 3.4.1 Deterministic models

#### 3.4.1.1 Basic EOQ model

There are a few basic assumptions regarding this model (Jablonský, 2007):

- The demand is known and constant – it is denoted with the symbol $Q$.
- The use of resources from the warehouse is uniform.
- The acquisition time of the deliveries is known and constant.
- The size of all deliveries is constant – it is denoted with the symbol $q$.
- The acquisition price is independent of the size of the order.
- Stock shortages are not considered.
- Replenishment of stock takes place at a single point in time.

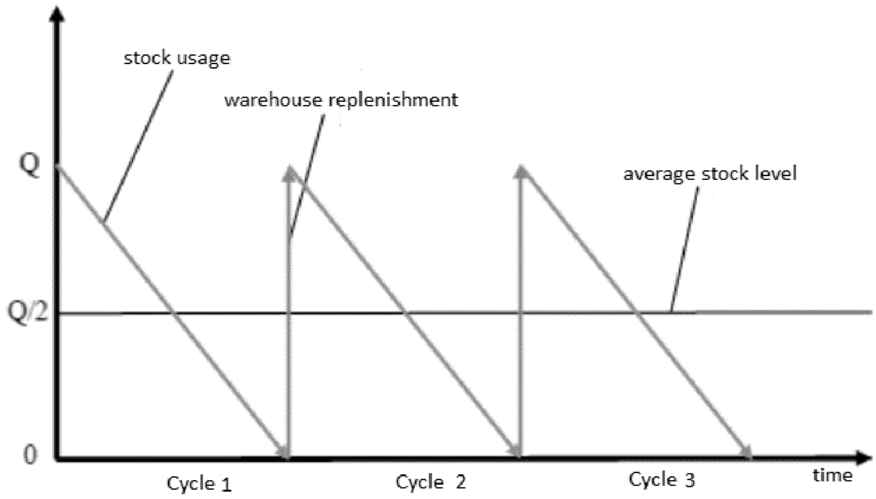


*Figure 3 – EOQ model, source: (Jablonský, 2007)*

So, this case occurs to be the simplest model, where to calculate the EOQ we need:

- Total cost *(TC),* which is calculated as the sum of the total annual storage costs $(c_s)$ and total annual fixed acquisition costs $(c_o)$ (Jablonský, 2007, p. 214):

$$TC = c_s + c_o \tag{1}$$

*or*

$$TC = \frac{Q}{2} * k_s + \frac{D}{Q} * k_o \tag{2}$$

- The minimum total costs occurs when the slopes of the two cost components (ordering and carrying cost) are equal and opposite in sign. In this particular case, this occurs where the two cost components are equal *(see Figure 4)*. This fact can be used for constructing the formula for the optimal order quantity:

$$\frac{Q}{2} k_s = \frac{D}{Q} k_o \tag{3}$$

$$Q^2 = \frac{2Dk_o}{k_s} \tag{4}$$

$$Q = \sqrt{\frac{2Dk_o}{k_s}} \tag{5}$$

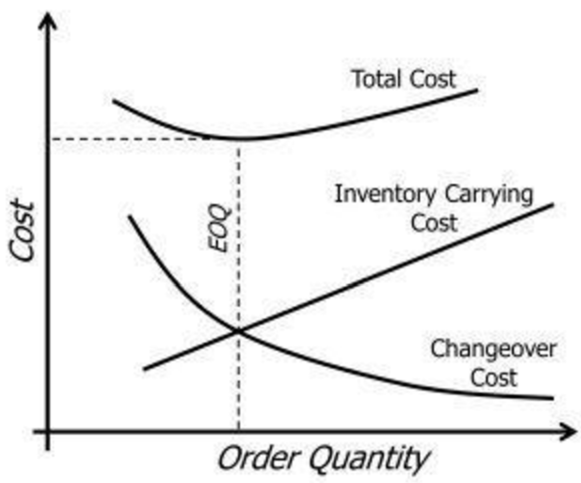


*Figure 4 – Graphical representation of cost functions and optimal order size (EOQ), source: (Anderson, et al., 2014, p. 412)*

In cases where the stockout is permitted, the following equation is used:

$$TC = c_s + c_o + c_n \,, \tag{6}$$

where $c_n$ are costs from lack of the stock (Hillier & Lieberman, 2001, p. 945).

#### 3.4.1.2 EOQ model with quantity discount

Quantity discounts are the price reductions for larger orders offered to customers to encourage them to buy in large quantities. The EOQ model with quantity discounts replaces given before assumption by a new assumption:

The unit cost of an item now depends on the quantity in the batch. In particular, an incentive is provided to place a large order by replacing the unit cost for a small quantity by a smaller unit cost for every item in a larger batch, and perhaps by even smaller unit costs for even larger batches (Hillier & Lieberman, 2001, p. 946).
Otherwise, the assumptions are the same as for the basic EOQ model.

The cost function must now consider not only the costs for storage and acquisition, but also the purchase price, because it may vary for different levels of orders (Anderson, et al., 2014, p. 426). The cost function can be expressed as:

$$TC = \frac{Q}{2} * c_s + \frac{D}{Q} * c_o + DC \, , \tag{7}$$

where:

- $c_s$ represents the cost to hold one unit in inventory for one year,
- $c_o$ represents the cost per order,
- annual purchase cost (annual demand $D$ and unit cost $C$) is included in the equation for total cost as shown.

#### 3.4.1.3 Just-In-Time model

Just in time is actually a well-developed inventory control strategy. Just-In-Time (JIT) inventory system places great value on minimizing stock levels and providing items just to an absolute minimum, so that items are available just in time when they are required.

This philosophy was first developed in Japan, starting with the Toyota Company in the late 1950s, and is partly responsible for the remarkable gains in Japanese productivity throughout much of the late 20th century (Hillier & Lieberman, 2001, p. 950). The just-in-time concept aims to keep stock levels very low, thereby reducing inventory costs. However, if order quantities are reduced below the economic order quantity level, order costs will increase and total costs will be higher than optimal. In order to implement the just-in-time concept, it is necessary that the order costs are somehow reduced from their previous value.

This model does not include any insurance stocks. Insurance stocks are not formed and in addition they look for reserves in reducing unnecessary inventory in warehouses (Dömeová & Beránková, 2004, p. 26).

### 3.4.2 Probabilistic or stochastic models

In the following chapter there are models with unknown demand. Let's consider a model with the same assumptions as the deterministic model has, but the amount of demand in a given period of time is random with a certain probability distribution.

The goal is still the same – to minimize the total cost of inventory, which is combined from storage, acquisition and shortage costs. Shortage may or may not occur during (possibly random) lead times. That is why calculating the shortage cost is considered a problem as well in this model.

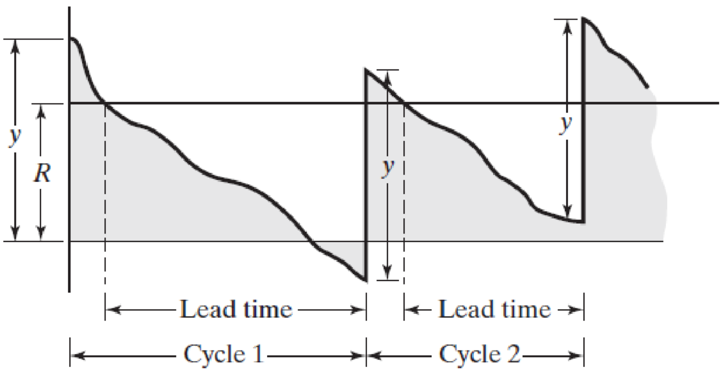


*Figure 5 – Probabilistic inventory model with shortage, source: (Taha, 2017, p. 614)*

There are two kinds of models in this case (Jablonský, 2007, p. 231):

- Models with stochastic demand and multiple reordering of the stock.
- Models with stochastic demand and single order.

However, due to the experience gained during the cooperation with the "Imperial Sushi" restaurant, only the first model will be considered further. Models with single orders are just not used in a restaurant business.

#### 3.4.2.1 Model with stochastic demand and multiple reorder

The goal is to define the size of the order and the level of the order in that way, so the total cost, including the loss due to the non-satisfied demand was minimal. Demand here cannot be postponed and in case of its unsatisfaction losses are calculated as loss of profit plus other losses, like damage to reputation. The optimal size of the order is recommended to be the same as in the deterministic model (Dömeová & Beránková, 2004, p. 29).

There are five main assumptions in this model (Dömeová & Beránková, 2004, p. 29) they are:

- The acquisition period is known and constant.
- The cost of shortage of stock relates to the shortage of one unit regardless of duration of the deficiency.
- The demand during the acquisition time has normal distribution.
- The optimal order level is higher than the average value of demand in the acquisition period.
- Insurance stock is positive.

It is recommended to use the same formula for calculating the optimal order size as in the deterministic model, however, instead of total annual demand $(D)$ estimation of the total annual demand $(\overline{D})$ is used:

$$Q = \sqrt{\frac{2\overline{D}k_o}{k_s}} \tag{8}$$

It is possible to calculate the order size and the order level simultaneously, but separate calculation brings a simplification.

To determine the order level, we assume the order level equals to the mean value of the consumption during the acquisition period $\overline{M}$, which we increase by the insurance stock $w$:

$$R = \overline{M} + w \tag{9}$$

Although other probability distributions can be used to express the demand during the review period plus the lead-time period if the normal probability distribution is used, the general expression for $R$ is:

$$R = \overline{M} + Z * \sigma_M \, , \tag{10}$$

where $Z$ is the number of standard deviations necessary to obtain the acceptable stock-out probability. It is either obtained from the table of values of the normal standardized distribution function or calculated with Excel formula.

In other words, the insurance stock $w$ can be also expressed as:

$$w = Z * \sigma_M \tag{11}$$

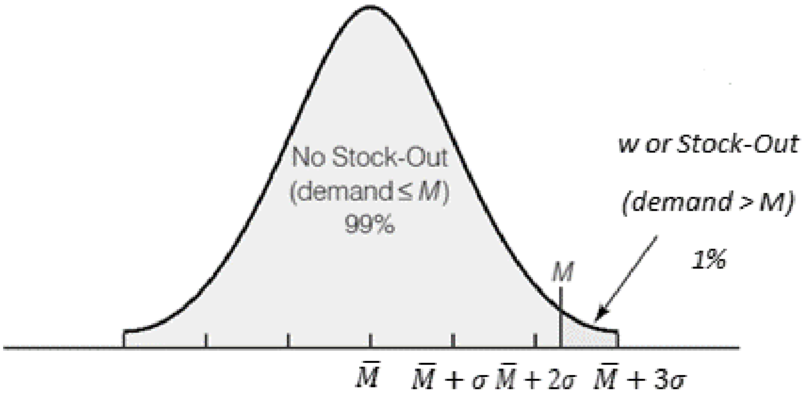


*Figure 6 – Normal distribution of demand during lead time, source: (Anderson, et al., 2014, p. 439)*

The remaining step is to find the proper $R$ for the following equation (Hillier & Lieberman, 2001, p. 960):

$$F(R) = probability(M \leq R) \tag{12}$$

The desired probability (the demand during the lead time will be met by the stock) can be expressed with the following equation (Dömeová & Beránková, 2004, p. 31):

$$F(R) = 1 - \frac{k_s * Q}{k_n * \bar{D}} \tag{13}$$

# 4 Practical part

## 4.1 Characteristics of the company

Imperial sushi s.r.o. is a young company, which was founded during the Covid-19 in 2020 with the main idea of delivering sushi. The company started to exist with two employees and only rented a part of foreign kitchen with 5 $m^2$. After the pandemic Imperial sushi started to grow fast and finally expanded to three fully autonomous restaurants in Prague and Plzen. The company is represented on all existing food delivering platforms in the Czech Republic, like Foodora, Wolt and Bold food. Moreover, in the last year the restaurant has developed its own food delivery application with more favorable offers for customers available on the Apple store and Google store.

Further in the practical part only the main restaurant based in Žižkov in Prague will be considered. That restaurant currently employs 15 employees:

- 1 manger,
- 1 chef-cook,
- 6 cooks,
- 3 barmen,
- 1 cleaning woman,
- 3 drivers for delivery.

The Imperial Sushi company has several product suppliers. Each of three main supplier supplies different types of products: fresh fruit and vegetables, fish and Japanese products. Japanese products are handled by Bonsan Holding. In the following chapter there will be done an ABC analysis of products from two main suppliers of fish and Japanese goods.

## 4.2 ABC analysis

With the date absorbed from the company I have done the ABC analysis of the main items of the inventory. The analysis included thirty daily use goods, without which it is impossible for a business to run smoothly. Based on this analysis, the business can understand which products to pay more attention to when purchasing and conducting inventory.

The revenue of each item was calculated as the product of the average annual demand for that item by the price per unit. Further, it was calculated what percentage each item represents in total annual revenue. Afterwards, according to cumulative share of sales, categorized into three groups with boundaries spaced as follows (cumulative share is denoted as CS):

- Category A: $CS < 70\%$
- Category B: $70\% < CS < 95\%$
- Category C: $95\% < CS$

| TITLE | REVENUE, KC | % OF REVENUE | % OF CUM. | CATEGORY |
|---|---|---|---|---|
| ***SALMON, 1 KG*** | *811760* | *19%* | *19%* | *A* |
| ***TUNA, 1 KG*** | *467200* | *11%* | *30%* | *A* |
| ***EEL FILET, 9oz*** | *319740* | *8%* | *38%* | *A* |
| ***CAVIAR "TOBIKO", 0,4 KG*** | *300760* | *7%* | *45%* | *A* |
| ***SMOKED SALMON, 0,9 KG*** | *300057* | *7%* | *52%* | *A* |
| ***TEMPURA FLOUR , 1 KG*** | *271195* | *6%* | *58%* | *A* |
| ***SHRIMPS "NABASHI", 0,4 KG*** | *217540* | *5%* | *64%* | *A* |
| ***SEAWEED LEAFS "NORI GOLD", 50 KS*** | *196852* | *5%* | *68%* | *A* |
| ***SALAD "WAKAME" , 1 KG*** | *192603* | *5%* | *73%* | *B* |
| ***RICE "SHINJU MAI" 10 KG*** | *182500* | *4%* | *77%* | *B* |
| ***CREAMCHEESE “PHILADELPHIA“, 1,6 KG*** | *160965* | *4%* | *81%* | *B* |
| ***PICKLED PUMPKIN "DARUMA", 1 KG*** | *113296* | *3%* | *84%* | *B* |
| ***SHRIMPS SIZE 26-30, 1 KG*** | *89425* | *2%* | *86%* | *B* |
| ***CRAB MEAT “SURUMI-MAKI“ , 1 KG*** | *76011* | *2%* | *88%* | *B* |
| ***WASABI POWDER "SHIRAKIKU", 1 KG*** | *70628* | *2%* | *89%* | *B* |
| ***UNAGI SAUCE "DARUMA", 1,8 L*** | *64614* | *2%* | *91%* | *B* |
| ***SRIMPS "EBI 4L", 30 KS*** | *59834* | *1%* | *92%* | *B* |
| ***PICKLED RADISH "DARUMA", 1 KG*** | *58765* | *1%* | *94%* | *B* |
| ***GINGER, 1 KG*** | *48859* | *1%* | *95%* | *B* |
| ***VINEGAR "MIZKAN SHUEHIRO", 20 L*** | *43560* | *1%* | *96%* | *C* |
| ***TUNA FLAKES "YAMABUKI", 0,5 KG*** | *41227* | *1%* | *97%* | *C* |
| ***OMELETTE "TAMAGO", 0,4 KG*** | *35051* | *1%* | *98%* | *C* |
| ***TOFU "MODRÝ MORINYU", 0,3 KG*** | *31865* | *1%* | *98%* | *C* |
| ***DRESSING "GOMA", 1 L*** | *20128* | *0%* | *99%* | *C* |
| ***SEASONING "SHIMAYA", 0,5 KG*** | *19820* | *0%* | *99%* | *C* |
| ***SEAWEED "KOMBU"*** | *13469* | *0%* | *100%* | *C* |
| ***SAUCE "SRIRACHA CHILLI", 1 L*** | *6320* | *0%* | *100%* | *C* |
| ***MANGO SAUCE "CHUTNEY", 0,4 KG*** | *4380* | *0%* | *100%* | *C* |
| ***SALT, 1 KG*** | *3577* | *0%* | *100%* | *C* |
| ***SUGAR, 1 KG*** | *3249* | *0%* | *100%* | *C* |
| | | | | |
| **TOTAL:** | **4225248** | **100%** | | |

*Table 4 – ABC analysis, source: own author's edition.*

The total amount of revenue equals to *4 225 248 Kč*. Category *A* includes goods which total revenue equals to *2 885 104 Kč* (8 items); category *B* includes goods which total revenue equals to *1 117 500 Kč* (*11* items); category *C* includes goods which total revenue equals to *222 643 Kč* (11 items). The number of items and the share of each category in total revenue is expressed in Table 5 and shown in Figures 8 and 9.

| Category | Share from total revenue (%) | Value (Kč) | Number of items | Share from total amount (%) |
|---|---|---|---|---|
| A | 68% | 2885104 | 8 | 27% |
| B | 26% | 1117500 | 11 | 37% |
| C | 5% | 222643 | 11 | 37% |
| **Total** | **100%** | **4 225 248** | **30** | **100%** |

*Table 5 – Share of ABC categories in total revenue, source: own author's edition.*

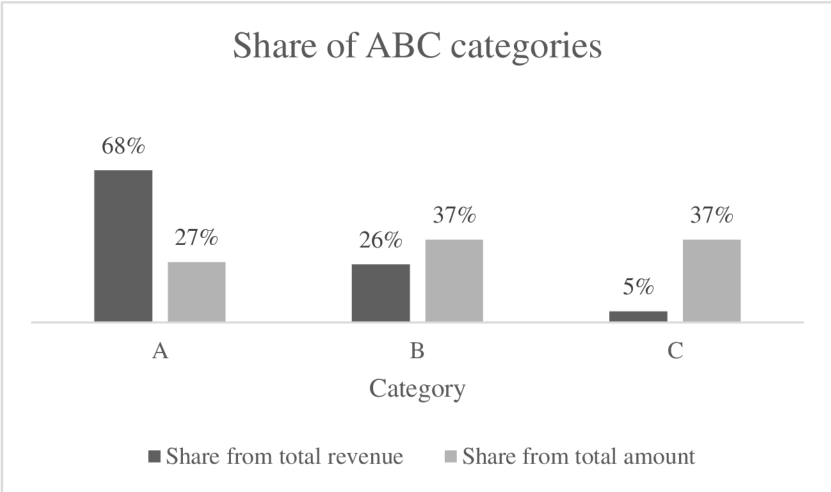


*Figure 7 – Share of ABC categories, source: own author's edition.*

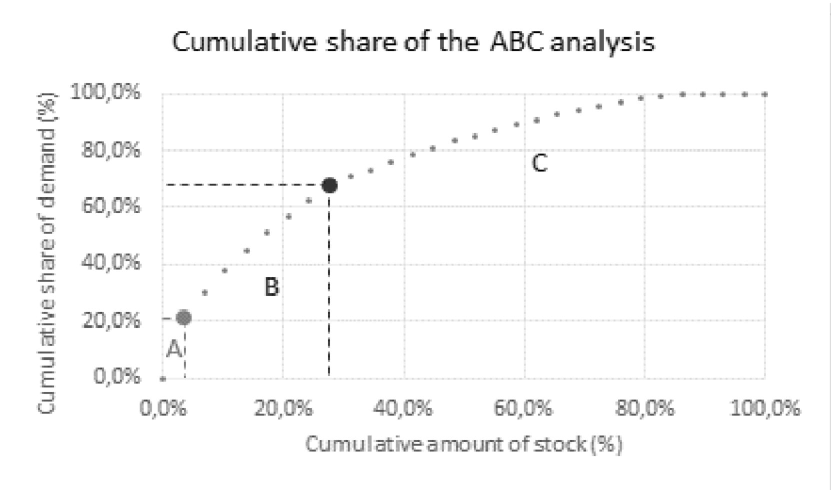


*Figure 8 – Cumulative share of ABC categories, source: own author's edition.*

## 4.3 Choice of the item for further analysis

As can be seen from the analysis in *Table 4*, the most profitable products of this business are different species of fish. However, counting the inventory of this type of perishable product is an incredibly complex process that cannot be touched upon in this thesis. Therefore, it was decided to select product “SEAWEED NORI GOLD, 50 PCS” for further analysis. This product is also included in the “A” category of the restaurant’s everyday stock. It is nori seaweed, which is used in one or another way to make almost every type of sushi on the restaurant's menu.

**Additional information:**

Price for one unit (2023): *134,83 Kč* without DPH

Package: *50* pieces

Sold: in boxes of *10* packages per box

Storage: in a dry, dark place ($10\ m^2$ storage place) in plastic packages inside cartoon boxes

Average stock level: *2,5* boxes

Average demand per day: *0,42* box

Average annual demand: *153,3* boxes

Storage cost $k_o$: *2,5 Kč*

Lead time: *3 days*

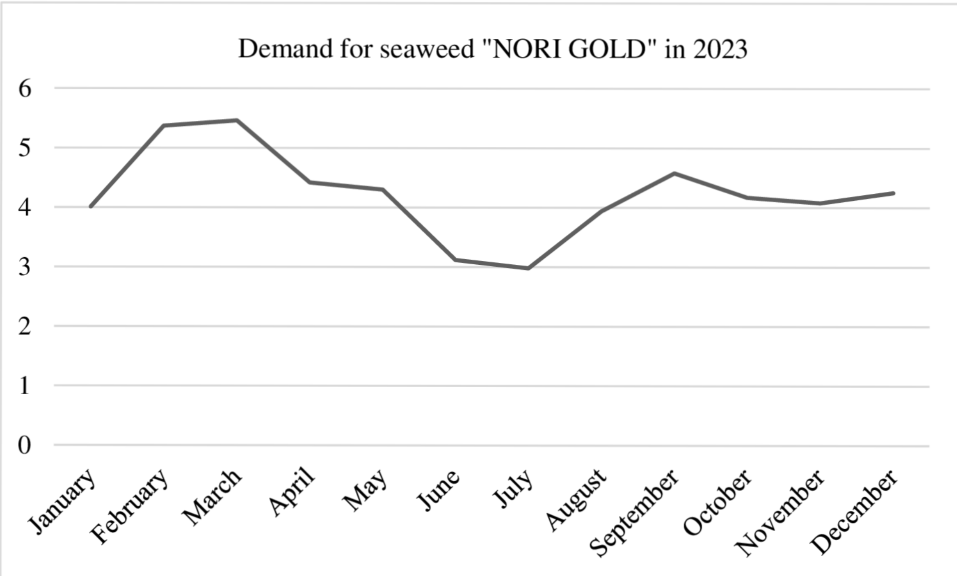


*Figure 9 – Demand for seaweed "NORI GOLD" in 2023, source Imperial Sushi s.r.o., own author's edition.*

## 4.4 Inventory models

### 4.4.1 Basic EOQ model

From chapter *3.4.1.1* of the theoretical part and specifically from equation (5), it is known that EOQ equals to:

$$Q = \sqrt{\frac{2Dk_o}{k_s}}$$

To calculate optimal order size you need to know the annual storage cost *($k_s$)*, fixed acquisition cost ($k_o$) and average annual demand *($D$)*, which in our case are:

$k_o$ = *10 Kč*;

$k_s$ = *2,5 Kč*;

*D = 153,3 boxes ≈ 153 boxes*

Further we got the following equation:

$$Q = \sqrt{\frac{2*153*10}{2,5}} = 35 \text{ boxes.}$$

This suggests that the manager of Imperial Sushi restaurant should order 35 boxes of seaweed nori at a time to minimize the total annual cost associated with ordering and holding inventory.

### 4.4.2 EOQ model with quantity discount

In this chapter there will be a simulation of a model with a quantity discount. Unfortunately, in the real-life scenario there was no such a situation during my cooperation with the Imperial Sushi restaurant.

Let's assume that the expiry date of the chosen nori is coming up in 3 months and, therefore, the supplier ends up with the idea to organize sales for that item. If a customer takes a larger amount of nori, the supplier provides the following discount: from 10 to 15 boxes of nori – 8% discount; 15+ boxes of nori – 13% discount.

For better clarity, let's make a table:

| Order amount (boxes) | Discount (%) | Price per unit (Kč) |
|---|---|---|
| *0-10* | *0* | *135* |
| *10-15* | *8* | *124* |
| *15+* | *13* | *117* |

*Table 6 – Simulation of the quantity discount (part 1), source: author's own edition.*

The objective is to determine if the discount offered has an economic profit for the restaurant.

$$D = 153\ boxes$$

$$k_o = 10\ \text{Kč}$$

Let's assume that the storage cost ($k_s$) is 10% of the purchasing price, from that the following table is done:

| Order amount (boxes) | Discount (%) | Price per unit (Kč) | Storage cost (Kč) |
|---|---|---|---|
| *0-10* | *0* | *135* | *13,5* |
| *10-15* | *8* | *124* | *12,4* |
| *15+* | *13* | *117* | *11,7* |

*Table 7 – Simulation of the quantity discount (part 2), source: author's own edition.*

Firstly, the value of $Q$ for each case should be calculated. For calculating $Q$ the following formula (5) is used:

$$Q = \sqrt{\frac{2Dk_o}{k_s}}$$

$$Q_1 = \sqrt{\frac{2 * 153 * 10}{13{,}5}} = 15{,}05\ boxes$$

$$Q_2 = \sqrt{\frac{2 * 153 * 10}{12{,}4}} = 15{,}7\ boxes$$

$$Q_3 = \sqrt{\frac{2 * 153 * 10}{11{,}7}} = 16{,}1\ boxes$$

Now the validity of the outcomes should be checked:

$Q_1 = 15{,}05$ , which is greater than the upper bounder of the given discount rate. So, the outcome is not valid. $Q_1$ equaled to 10 should be used instead.

$Q_2 = 15{,}7$ , which is also not valid. $Q_2$ equaled to 15 should be used instead.

$Q_3 = 16{,}1$ , which is finally a valid outcome.

Afterwards, Total Cost per each outcome should be calculated separately to determine the most suitable scenario. Formula (7) from the chapter *3.4.1.2* should be used:

$$TC = \frac{Q}{2} * c_s + \frac{D}{Q} * c_o + DC$$

$$TC_1 = \frac{153}{10} * 10 + \frac{10}{2} * 2{,}5 + 153 * 135 = 20820{,}5\ Kč$$

$$TC_2 = \frac{153}{15} * 10 + \frac{15}{2} * 2{,}5 + 153 * 124 = 19093\ Kč$$

$$TC_3 = \frac{153}{16} * 10 + \frac{16}{2} * 2{,}5 + 153 * 117 = 18016\ Kč$$

$$18016 < 19093 < 20820{,}5$$

Accordingly the calculations, the management of the Imperial Sushi restaurant should use the provided discount and order at least *16* boxes of nori to minimize their expenses. In fact, the management should worry if the restaurant succeeds in using the nori with a short expiry date (*3* months), as the average usage of nori is *0,42* boxes a day, that means that *16* boxes will be used in approximately *38* days. That means that the restaurant can order even more. Let's find out what is the maximum quantity of boxes the restaurant can order to prevent the use of spoilt goods. For that it is needed to calculate how many boxes will be used in *90* days (goods with discount has *3* months expiry date).

$$The\ amount\ of\ boxes\ used\ in\ 90\ days\ = 90 * 0{,}42 = 37{,}8 \approx 37$$

The amount should be rounded to *37* here because the restaurant cannot exceed the amount of goods with a short expiry date, that is why it is better to order a little bit less. The last step here is calculating total savings from ordering with discount. However, taking into account the expiry date the demand should be changed to *37* and the following calculations will only show saving for this amount. For ordering size without discount (*4* boxes) an average size of order the restaurant does while ordering this item was taken.

For better clarity the final table in this chapter is done:

| | *Without discount* | *With 13 % discount* |
|---|---|---|
| ***C*** *(Kč)* | *135* | *117* |
| $k_s$ *(Kč)* | *13,5* | *11,7* |
| $k_o$ *(Kč)* | *10* | *10* |
| ***Q*** *(boxes)* | *4* | *37* |

*Table 8 – Simulation of the quantity discount (part 3), source: author's own edition.*

1. Saving due to the price reduction:

$$c_Q = P * k_Q = 37 * 18 = 666\ Kč$$

2. Increasing of the storage cost:

$$c_s{}' = \frac{Q}{2} * k_s - \frac{Q'}{2} * k'_s = \frac{4 * 13{,}5}{2} - \frac{37 * 11{,}7}{2} \approx -190\ K\check{c}$$

3. Decreasing of the acquisition cost:

$$c'_o = \frac{P}{Q} * k_o - \frac{P}{Q'} * k'_o = \frac{37 * 10}{2} - \frac{37 * 10}{37} = 82{,}5\ K\check{c}$$

4. $Total\ saving\ = 666 - 190 + 82{,}5 = 558{,}5\ K\check{c}$

In conclusion to this chapter, it can be said that in case this simulation happens in real life, Imperial Sushi should use *13%* discount for nori with short expiry date and order *37* boxes to succeed to use all ordered goods with discount in timeframe of *3* months. Total saving will be *558,5 Kč*, which does not seem to be a huge amount of money, but for a small business it may be a good index.

### 4.4.3 EOQ model with stochastic demand and multiple reorder

In the following chapter we will calculate and analyze optimal ordering level and optimal order quantity in a stochastic demand model.

Steps of the solution:

1. Calculating the optimal order quantity $Q$.
2. Calculating the desired probability $F(R)$.
3. Finding the coefficient of security $Z$.
4. Calculating the optimal ordering level $R$

For this one value will be needed, which has to be determined in advance before starting the main calculations for deeper understanding. It is the cost of possible loss caused by a lack of goods ($k_n$). The shortage of nori has never happened, so, let's simulate it.

The restaurant approximately uses *210* leaves a day (or *0,42* boxes) in proportion:

- *210* for maki-sushi with average price *131,5 Kč* per *1* maki-roll,
- *105* for uramaki-sushi with average price *339 K*č per *1* uramaki-roll,
- *52,5* for futomaki-sushi with average price *275 Kč* per *1* futomaki-roll.

For preparing maki and uramaki it is used *½* of the nori leaf. For preparing futomaki it is used *1* full nori leaf.

So, if there was a shortage of nori in the Imperial Sushi restaurant, minimum possible profit loss can be calculated as:

$$210 * 131{,}5 + 105 * 339 + 52{,}5 * 275 \approx 77700\ Kč.$$

This sum also should be multiplied by *0,42*, which equals approximately *32600 Kč*. This is average minimum loss per day in case of shortage of nori in the restaurant. Let's take this value for further calculation without adding any other possible loss costs.

Further there is the following input data:

$$k_o = 10\ Kč$$

$$k_s = 2{,}5\ Kč\ per\ unit\ * \ 153\ (\bar{D}) = 383\ Kč$$

$$Lead\ time\ = \ 3\ days$$

$$\bar{M} = \ 0{,}42 * 3 = 1{,}26\ boxes$$

$$\sigma_M = 0{,}072 * 3 = 0{,}216\ boxes$$

$$k_n = 32600\ Kč$$

1. Calculating the optimal order quantity *Q*, using the following formula (8):

$$\mathrm{Q} = \sqrt{\frac{2\bar{D}k_o}{k_s}}$$

$$Q = \sqrt{\frac{2 * 1{,}26 * 10}{2{,}5}} = 3{,}17\ \approx 3\ boxes$$

2. Calculating the required probability F(R):

$$F(R) = \ 1 - \frac{k_s * Q}{k_n * \bar{D}}$$

$$F(R) = 1 - \frac{383 * 3{,}17}{32600 * 153} = 0{,}9998$$

3. Using Excel and formula "norm.s.inv(0,9998)" the following value for coefficient of security Z = 3,54 was gained:

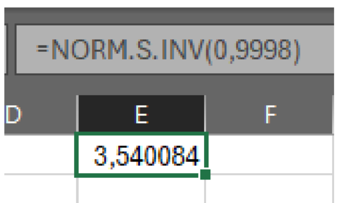


*Figure 10 – Excel formula "norm.s.inv", source: author's own edition.*

4. Calculating the optimal ordering level R:

$$R = \bar{M} + Z * \sigma_M = 1{,}26 + 3{,}54 * 0{,}216 = 2\ boxes$$

The conclusion in this chapter is following:
The management of the Imperial Sushi restaurant should place an order with the amount of 3 boxes, when the stock level of nori reaches the level of 2 boxes.

### 4.4.4 Just-In-Time model

Although the system was invented in Japan and should logically be a perfect fit for inventory management in a Japanese restaurant, there are several conditions for successful implementation of the system.

Firstly, in order to successfully implement this inventory management system, it is necessary to have a very close relationship with the supplier of goods. This means that the moment the restaurant uses the last leaf of nori, the supplier has to show up at the door with a new delivery. This is, of course, almost unbelievable, taking into consideration the limited hours of operation of the supplier.

Secondly, the fluctuations in demand also strongly influence this model. Although the total average annual, monthly or daily demand for products is known, there is always a deviation from it, which leads to the need to have a security stock of goods for this eventuality. This principle also prevents the model from being used in life with a live and unstable demand, which is exactly what Imperial Sushi restaurant has.

Nevertheless, in some cases this technique can be applied to the realities of a small restaurant.

## 4.5 Total inventory cost for chosen models

### 4.5.1 Total cost for basic EOQ model

For calculating the total cost of EOQ basic model the following formula (from chapter *3.4.1.1*) will be used:

$$TC = c_s + c_o + c_n$$

However, let's exclude the shortage cost, as shortage of nori has never happened in Imperial Sushi.

So, the formula will look like this:

$$TC = c_s + c_o$$

$$TC = \frac{153 * 10}{35} + \frac{35 * 2,5}{10} = 88\ Kč$$

### 4.5.2 Total cost for model with stochastic demand and multiple reorder

For calculating the total cost for the for model with stochastic demand and multiple reorder, the formula is basically this:

$$TC = c_s + c_o + c_w$$

$$TC = \frac{153 * 10}{3} + \frac{3 * 2,5}{2} + 0,8 * 2,5 \approx 516\ Kč$$

### 4.5.3 Total current cost

In the current situation the restaurant orders approximately *4* boxes of nori and takes *1* box as security stock. For calculating the total cost for current situation, let's use the same formula as in the previous chapter:

$$TC = c_s + c_o + c_w$$

$$TC = \frac{153 * 10}{4} + \frac{4 * 2,5}{2} + 1 * 2,5 = 390\ Kč$$

# 5 Discussion of the results

From the practical calculations the following results were gained:

- $TC\ (EOQ\ model) = 88\ Kč$
- $TC(Stochatic\ demand\ and\ multiple\ reorder) = 516 Kč$
- $TC\ (Current)\ =\ 390\ Kč$

As can be seen from the calculations, the cost of the second model is almost 6 times more expensive than the first one. This is due to the nature of the demand and the additional costs associated with it.

In the model with known and constant demand, the number of orders is much smaller, which positively affects the cost of this model. As discussed in the theoretical part, the optimal order quantity is reached when the acquisition cost is equal to the holding cost. In both cases for this model, the cost is equal to *44 Kč*. The optimal order quantity is *35* boxes in this case.

However, in real life it is not possible to follow this model and order so many boxes. This is at least because the warehouse is limited in size and there are many other items that need to be placed in it. The logical solution is to expand the warehouse by adding more shelves along the walls. Currently, the warehouse only has these shelves on one side. You can also extend the height of these shelves all the way to the ceiling and use a ladder if needed. Nori boxes do not take up much space (each box is *30x20x25cm*), also for storage of nori special temperature regulations are not needed. It is enough to keep them in a dark and dry place.

In the second case, with unknown and inconstant demand, it was calculated that the optimal level of placing a new order comes when there are 2 boxes of nori left in stock. In this case, the optimal amount of nori in a new order is 3 boxes. The cost of this model is significantly higher than the first one. This is due to the nature of fickle demand and the additional costs associated with it. This model implies the presence of insurance goods in case of increased demand or an increase in the lead time. Adding a shortage cost makes this model different from the basic one. However, in this particular case, the business seeks to appease *99.98%* of the demand for nori to prevent further colossal losses. In this regard, as mentioned above in the calculations, a shortage of this product has never happened before in the history of this restaurant, since the cost of this shortage is so critical that the shortage is simply unacceptable.

In this regard, the general conclusion for the Imperial Sushi company is following:

- Increasing storage space.
- Using the first model with an optimum order quantity of *35* boxes.
- Place a new order when the stock level of nori in the warehouse is equal to *2* boxes.

These points will result in savings of approximately *4,5* times on just one item from the entire inventory.

The Just-In-Time model can be applied in this case to solve the possible shortage. Since the restaurant uses its *2* own couriers every day to deliver food around Prague, there is always the possibility of sending one courier between the orders to the regular store to buy a couple packs of nori in case of emergency. Fortunately, nori is already sold in almost every grocery store nowadays.

Using the basic EOQ model has its advantages and disadvantages. The main advantage is, obviously, its total cost, which turned out to be the cheapest of all chosen models. The disadvantage of this solution is that the model is used with a constant and known demand, which sooner or later may lead to a shortage of goods. Nevertheless, a timely solution was proposed for this case as well.

Using the first model with known demand in combination with the Just-In-Time model in case of urgent need can lead to almost a fourfold reduction in costs on just one item from the entire inventory. Considering this result, the firm may decide to apply the theory and calculations of this paper to implement them in its inventory management in future.

# 6 Conclusion

In conclusion, this bachelor thesis has explored the complexities of inventory management in the context of Imperial Sushi, a sushi restaurant in Prague. Through a comprehensive analysis that combined theoretical frameworks with practical insights gained from the restaurant's data, several key findings have been identified.

First, by examining various inventory control models, such as the basic EOQ model, EOQ models with quantity discounts, Just-In-Time models, and stochastic demand models, the optimal values for order size, reorder level, and quantity discount simulations were identified. These models have provided valuable information on cost effective inventory management decisions.

The analysis has shown that certain models, such as model with the stochastic demand, has appeared to be more financially demanding. However, properly implemented basic EOQ model with the Just-In-Time principles can ultimately lead to significant savings and operational efficiencies.

The research also highlights the importance of adaptability and responsiveness in inventory management. While theoretical models provide a framework for decision-making, real-world constraints and uncertainties require a flexible approach. By utilising internal resources, such as using in-house couriers for emergency purchases, Imperial Sushi can effectively respond to unexpected fluctuations in demand or supply.

In essence, the recommendations from this research aim to optimize Imperial Sushi's inventory processes, leading to improved efficiency and cost effectiveness. By combining theoretical insights with practical calculations, it proposes a comprehensive solution that balances cost optimization with operational flexibility. As Imperial Sushi continues to evolve in a dynamic market environment, implementing these recommendations can position the restaurant for sustainable success and competitiveness.

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# 8 List of figures and tables

## 8.1 List of figures



## 8.2 List of tables