Probabilistic Forecasting and Inventory Optimization

Forecasts should only be made to help you make the right supply chain decisions.

In the next 1000 words, I'll show you **why point forecasts are inadequate** to make supply decisions. Instead, you'll see why **you need probabilistic forecasts to make informed decisions**.

Let's start with an example; we'll discuss theory after.

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Operational Decisions based on Demand Forecasts

You are managing a bakery. Every early morning you need to decide how much to bake for the day. As a bakery manager, this is the most important operational decision you need to make. And you need to make it every single day.

Let's imagine you forecast that you are going to sell 10 pieces of bread today.
How many should you bake?

Credit: https://en.wikipedia.org/wiki/Bakery#/media/File:MagasinDandoy.jpg

Well, if you think 2 minutes about this inventory optimization question, you'll realize that you miss most of the puzzle pieces.

- How much does it **cost** to bake one bread?
- What is the **margin** per bread?
- What is the bread daily **demand distribution**?

(for the sake of conciseness, we'll leave the question of lead times out of this article)

Cost/Profitability Impact

Let's imagine that baking one bread costs 0.5€ and that you sell them at 1.5€ each. Based on this information, it seems that you would be better off having a few extra loaves of bread (0.5€ production cost) rather than being short by a few pieces (1€ opportunity cost).

But still, we do not know how many breads we should bake: 15? 20? 45?

> *The higher the products' margin and the lower the costs, the more you should store (as risks are low and rewards are high). To assess how much to inventory you need, a good understanding of your cost structure is as important as a good understanding of your demand.*

> *In practice, bakers hate to throw away food. So, they usually plan production not to have leftovers. We could include this leftover-aversion in our model as an extra penalty incurred when there is any excess inventory.*

Probabilistic Forecasts and Demand Distribution

The piece of information you are missing to make the right decision is a probabilistic view of what could possibly happen during a given day.

We need to know the probability of selling 1, 2, 3–25 pieces of bread in one day. We can then monetize every possible supply scenario using this information (*What might happen if I bake X pieces of bread?*). And choose our favorite one.

> *Looking at the expected demand distribution on a Monday and my costs, I will bake 15 breads to maximize my expected profits.*

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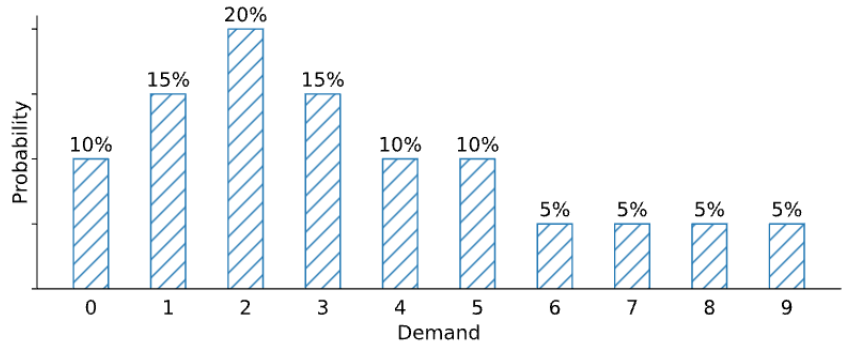
Let's look at the theory to understand how we will use probabilistic forecasts to optimize our (inventory) decisions.

Point Forecasting vs. Probabilistic Forecasting

- **Point Forecast**: associate the future with a single expected outcome, usually an average expected value (not to be confused with the *most likely* outcome). Example: *We forecast to sell 1000 units next month.*
- **Probabilistic Forecast**: allocates a probability for different events to happen. See Figure below for an example.



Example of a probabilistic forecast. Copyright: Nicolas Vandeput

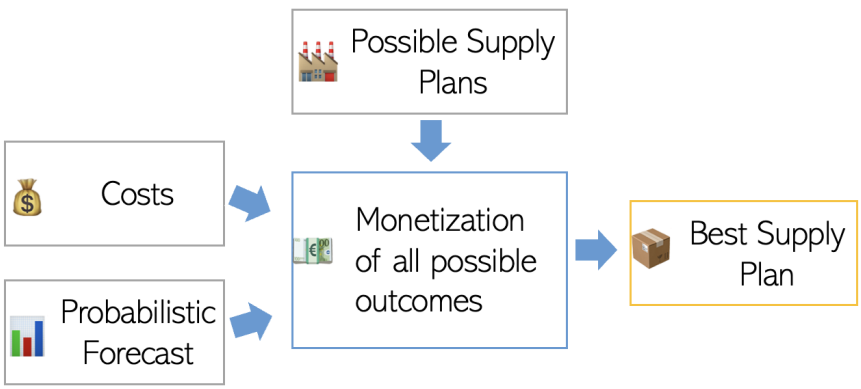
Naturally, we live in a random world where probabilistic forecasts make more sense than point forecasts. We can never be *absolutely* sure about the future. So, we should place bets today based on a range of possible futures and their respective likelihoods. Poker players understand this really well.

- **Example**. No one will forecast the outcome of rolling a die as 3.5 (the average expected value). Instead, we understand that we have 1 chance of out 6 to get any result from 1 to 6.

The same holds for supply chain demand. The demand for our bread *might* be 10, but it could also be 5 or 15. What is important is to estimate the likelihood of all these values.

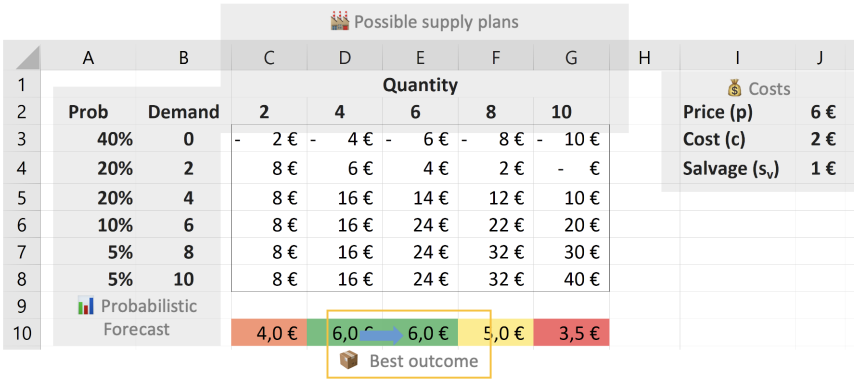
Probabilistic Forecasting & Inventory Optimization

Let's outline how you should use probabilistic forecasts to optimize your (inventory) decisions.



How to optimize supply (inventory) decisions. Copyright Nicolas Vandeput

1. Generate a demand probabilistic forecast (showing the % of likelihood to get a specific demand amount).
2. List the possible supply plans (*how much to supply?*). Supply constraints—— such as batch size—might restraint the number of possible scenarios.
3. Give an expected value to each scenario based on all the possible outcomes (weighted by their likelihood to happen).
4. Pick your favorite scenario.



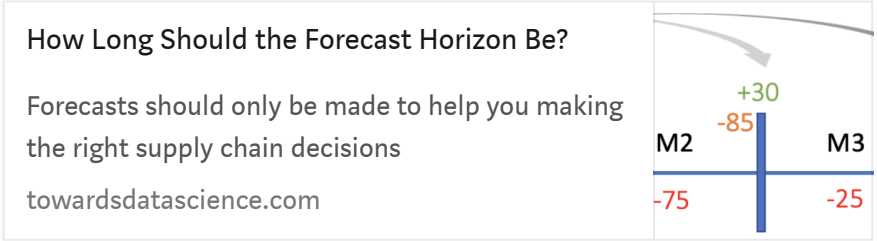
Supply decision optimization. Copyright: Nicolas Vandeput

Newsvendor vs. Multi-periods Planning

Some of you might have recognized the usual newsvendor problem in the previous example. Indeed, for the sake of conciseness, we left the question of (stochastic) lead times out of scope. Nevertheless, the story would be the same if we framed it this way:

> *You are a supply planner. Your main supplier is quoting you a lead time of 3 months and you make monthly orders. You currently have 100 pieces in stock. You know the supply plan for the next months (incoming orders) as well as the probabilistic forecast for the next 6 months. How much should you order?*

Actually, I explain this case here:



Conclusion: Should you use probabilistic forecasting?

Point forecasts are of low interest when it is about making decisions.

You forecast to sell 1000 units next month, but it is of limited help to determine how much you should produce.

Instead, probabilistic forecasts combined with relevant financial information will allow you to make the optimal decision.

You estimated next month's demand distribution. You know your margin and cost. You can make an informed decision on how much to buy to optimize your costs.

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👉 **Let's connect on LinkedIn!**

Acknowledgments

Michael Gilliland

About the Author

Nicolas Vandeput is a supply chain data scientist specialized in demand forecasting and inventory optimization. He founded his consultancy company SupChains in 2016 and co-founded SKU Science —a fast, simple, and affordable demand forecasting platform—in 2018. Passionate about education, Nicolas is both an avid learner and enjoys teaching at universities: he has taught forecasting and inventory optimization to master students since 2014 in Brussels, Belgium. Since 2020 he is also teaching both subjects at CentraleSupelec, Paris, France. He published *Data Science for Supply Chain Forecasting* in 2018 (2nd edition in 2021) and *Inventory Optimization: Models and Simulations* in 2020.