

# Integrated forecasting and inventory management in retailing - where it matters most with perishable products

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Marketing Analytics  
and Forecasting



Lancaster University  
Management School

# Agenda

## ➡ Practical relevance

Forecasting and inventory management

The data-driven newsvendor model

# Food waste as global challenge

Friday 02 September 2016

LANCASTER  
GUARDIAN

News Traffic and Travel Crime Weather Politics Business

## We could feed whole countries with the amount we waste in the UK

In the retail sector alone, 1.6m tonnes of per



<https://www.lancasterguardian.com/food-waste-amount-y>

MAY 18, 2019

the japan times

NATIONAL

Japanese convenience stores tackle food waste  
households and restaurants slow to get on board



Unsold food items from convenience stores are seen piled up in Chiba Prefecture. |

<https://www.japantimes.co.jp/news/2019/05/18/national-japanese-convenience-stores-tackle-food-waste-issue-households-restaurants-slow-get-board/#.XlaagWj7SUk>

The  
Guardian



Food

Americans waste 150,000 tons of food each day - equal to a pound per person

Research shows people with healthy diets rich in fruit and vegetables are the most wasteful and calls for better education for consumers

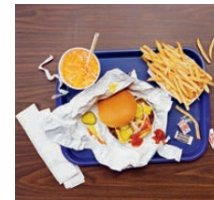
Oliver Milman

@olliemilman

Wed 18 Apr 2018 19:05 BST

<https://www.theguardian.com/environment/2018/apr/18/americans-waste-food-fruit-vegetables-study>

# 18 million tons of food waste per year (in Germany)



**Bulk  
consumer**  
19%

**End  
consumer**  
39%

	Harvest	Post-harvest	Processing	Distribution	
<b>Losses</b>	5%	9%	14%	14%	
<b>Probability of avoiding losses</b>	Low	Low	10%	90%	70%

All numbers based on empirical study by WWF, 2015

Source: [https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF\\_Studie\\_Das\\_grosse\\_Wegschmeissen.pdf](https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF_Studie_Das_grosse_Wegschmeissen.pdf)



# Potential solutions

## The Guardian

### French law forbids food waste by supermarkets

Food banks and other charities welcome law making large shops donate unsold food and stop spoiling items to deter foragers



▲ France wastes 7m tonnes of food annually. Supermarket c increase food donations. Photograph: Gary Calton for the Ot

France has become the first country in the world to ban throwing away or destroying unsold food to charities and food banks.

<https://www.theguardian.com/world/food-waste-by-supermarkets>

## INDEPENDENT

UK'S LARGEST QUALITY DIGITAL NEWS BRAND



Food waste contributes to eight per cent of global greenhouse gas emissions (Good to Go)

### MORRISONS SUPERMARKET £10 WORTH OF FOOD NEW FOOD V

The project aims to help customers on a budget and minimise food waste

Joanna Whitehead | @MsWhitehead100 |

Tuesday 26 November 2019 11:50 |

<https://www.independent.co.uk/life-style/food-and-drink/morrisons-food-waste-app-download-too-good-to-go-recycling-a9218031.html>

## RETAIL GAZETTE

### Tesco, Sainsbury's pledge to halve food waste by 2030

By Sahar Nazir - May 13, 2019



<https://www.retailgazette.co.uk/sainsburys-waitrose-pledge-halve-food-waste>

## Harvard Business Review

Competitive Strategy | How Large Food Retailers ...

COMPETITIVE STRATEGY

### How Large Food Retailers Can Help Solve the Food Waste Crisis

by Yasemin Y. Kor, Jaideep Prabhu, and Mark Esposito

December 19, 2017

Summary Save Share Comment Print \$8.95 Buy Copies



<https://hbr.org/2017/12/how-large-food-retailers-can-help-solve-the-food-waste-crisis>

# Trade-off between food waste and availability



<https://www.birminghammail.co.uk/whats-on/shopping/supermarket-shelves-pictured-eerily-empty-14953941>  
<https://www.dailyrecord.co.uk/news/scottish-news/glasgow-asda-giving-away-piles-13785158>



# Trade-off



## Leftover inventory

Annual waste

- 11.4% fruit
- 9.7% vegetables



## Stockout

Up to 30 % for perishable products

- 45% substitution
- 55% lost sales

➡ How can we match supply and demand?

Sources: Buzby et al., 2009; Kranert et al., 2012; Corsten and Gruen, 2003; ECR, 2003; <https://www.shopblogger.de/blog/plugin/tag/fehlartikel>  
<https://www.merkur.de/lokales/fuerstenfeldbruck/olching-ort29215/diebstahl-oder-umweltschutz-wegen-containern-angeklagt-10301509.html>;

# Agenda

Practical relevance

➡ Forecasting and inventory management

The data-driven newsvendor model



# Forecasting and inventory management

Forecasting	Inventory optimization
<ul style="list-style-type: none"><li>■ Demand uncertainty</li><li>■ Unobservable lost sales</li><li>■ External factors<ul style="list-style-type: none"><li>○ Price</li><li>○ Weather</li><li>○ Weekday</li></ul></li></ul>	<ul style="list-style-type: none"><li>■ Distribution assumptions</li><li>■ Underage vs. overage costs</li></ul>

**Data-driven newsvendor model: integrated approach**

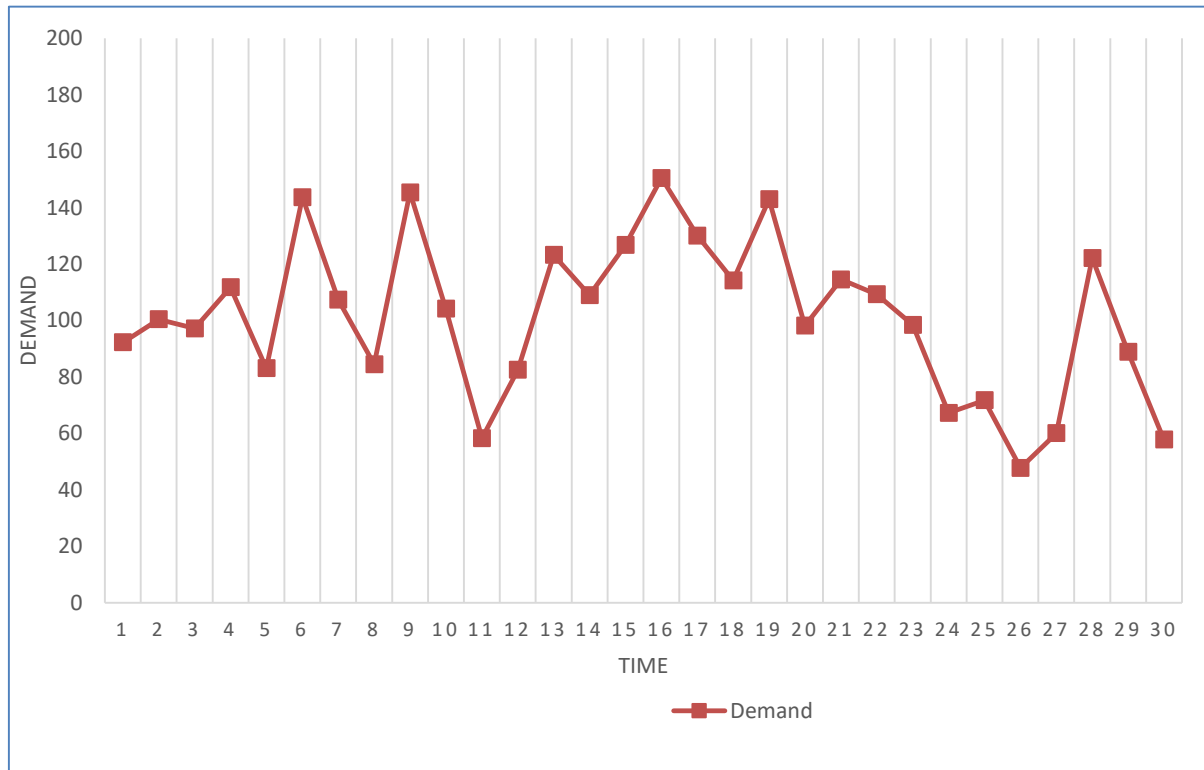
Joint work with Stefan Minner (TU Munich)

# Example

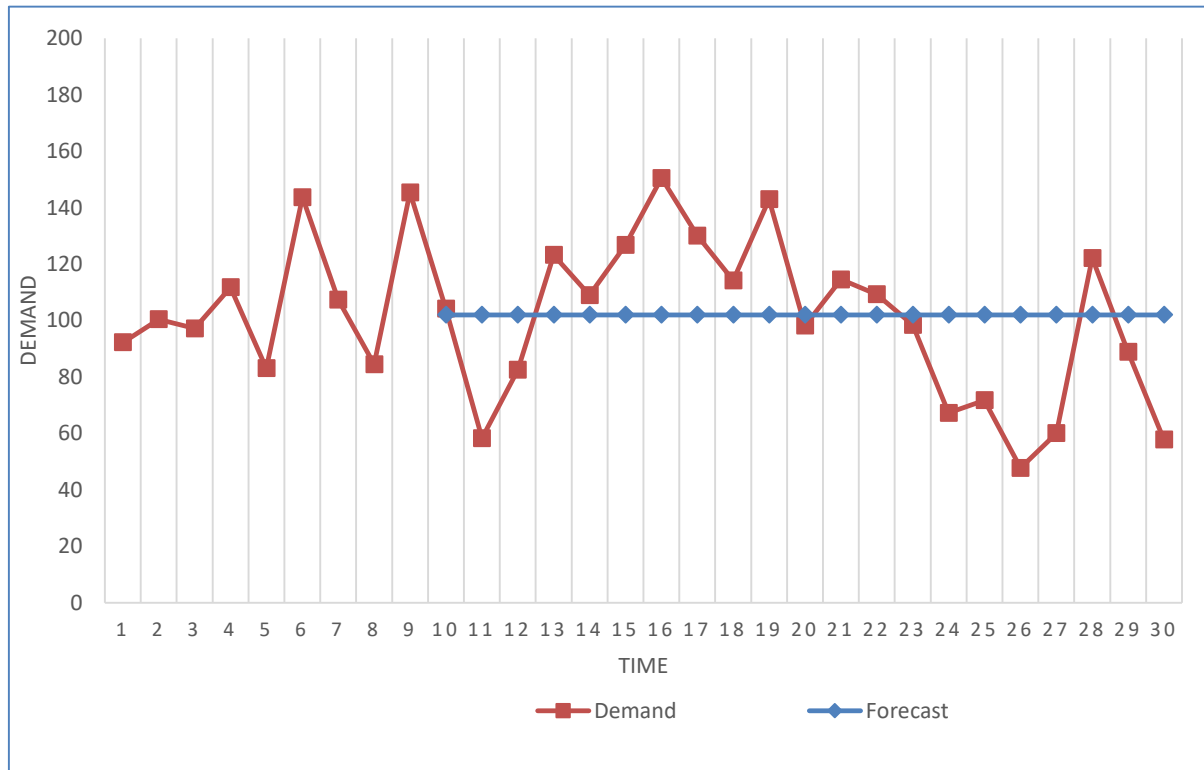


<https://www.mobile-kaffeebars.com/mobile-kaffeebar-detail/21ab6e4d>

# Example – Data

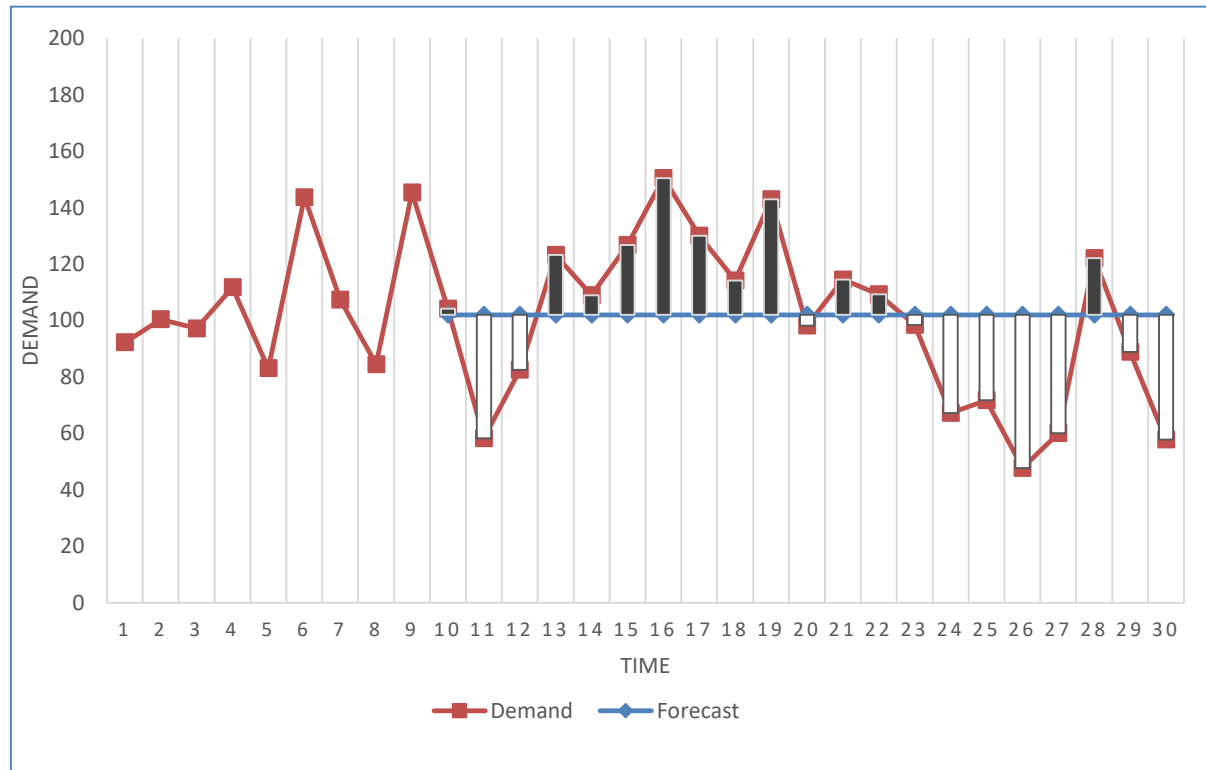


# Example – Point forecasts

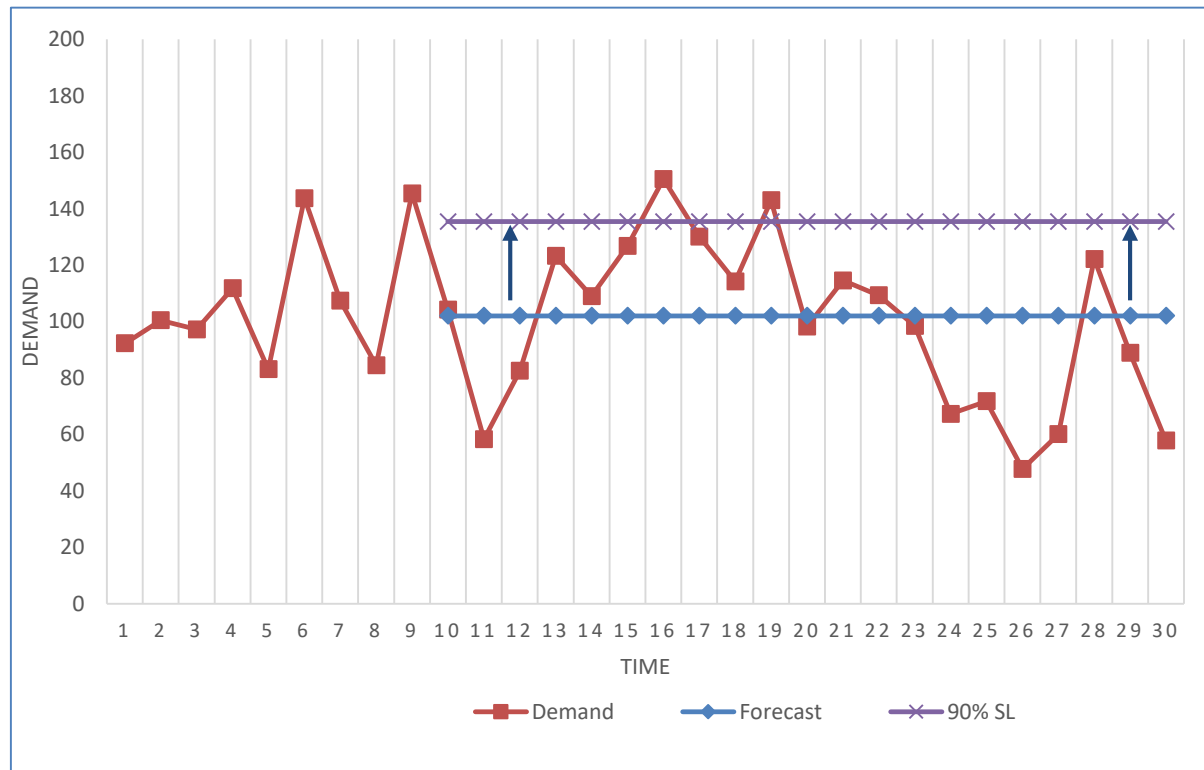




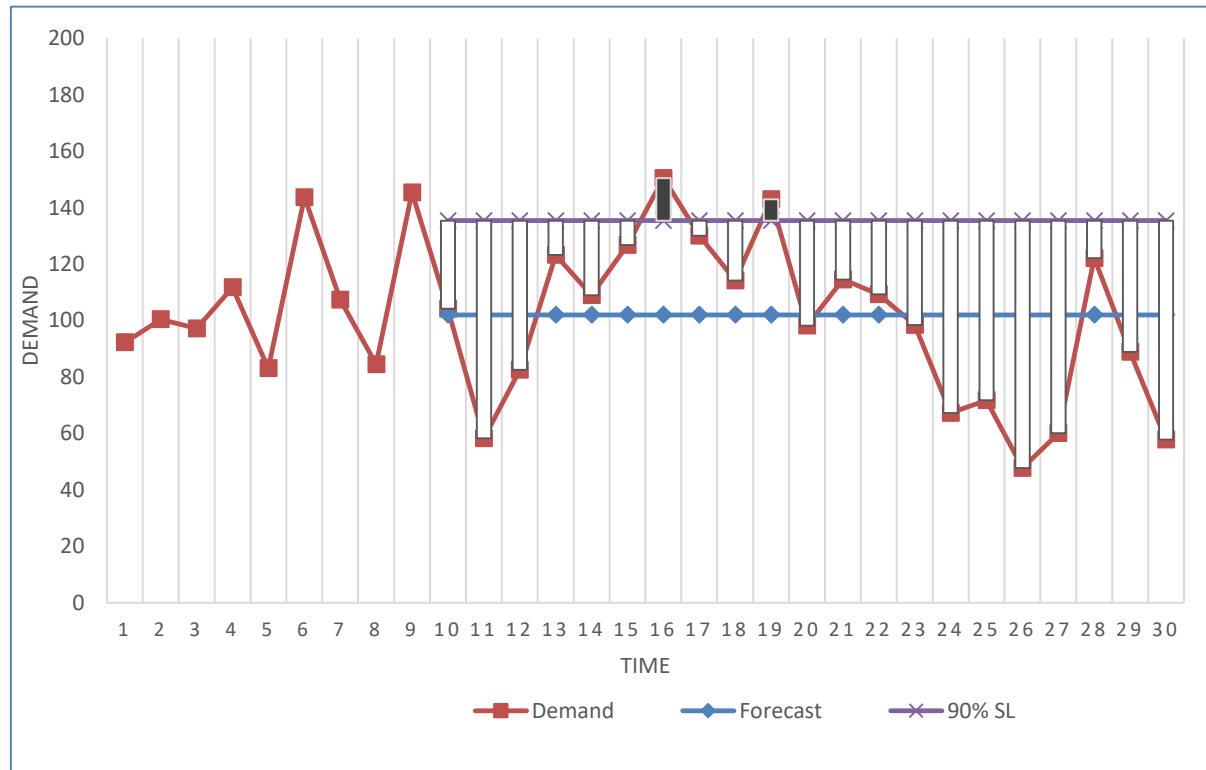
# Example – Service level perspective



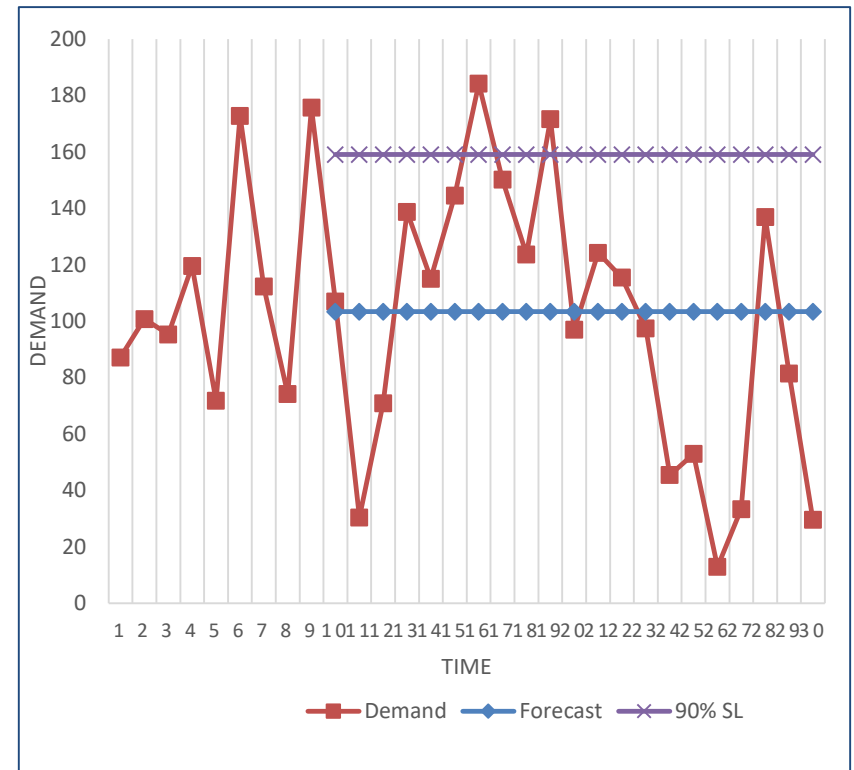
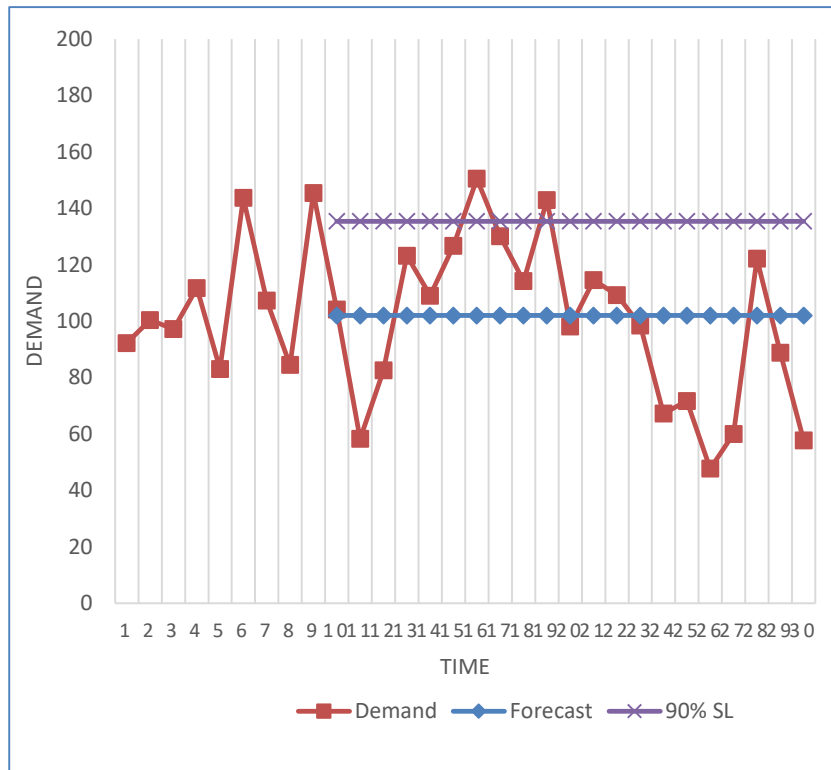
# Example – If underage costs > overage costs



# Example – Service level increases

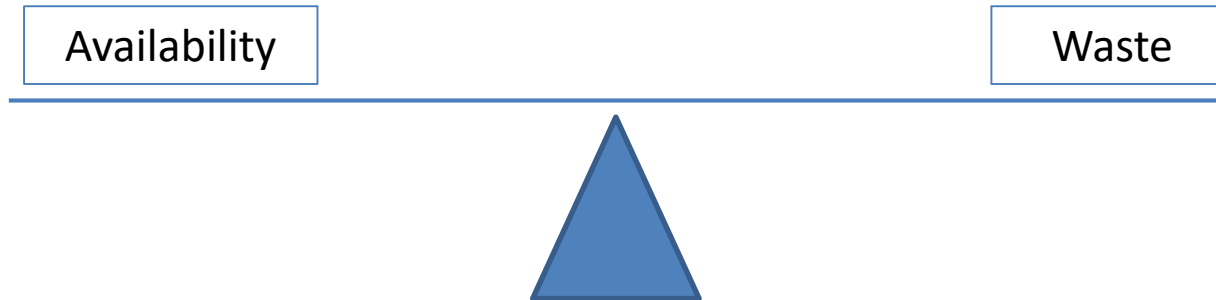


# Example – Importance of variability





# The newsvendor model



## Assumptions

- Order must be chosen before observing demand
- Demand is stochastic (uncertain)
- Only one production or procurement opportunity before selling season
- Leftover inventory at the end of the season has to be discarded or can be sold at salvage value

Source: <http://clipart-library.com/clipart/qcBbER4c5.htm>

# Agenda

Practical relevance

Forecasting and inventory management

➡ The data-driven newsvendor model

# The newsvendor model in retailing

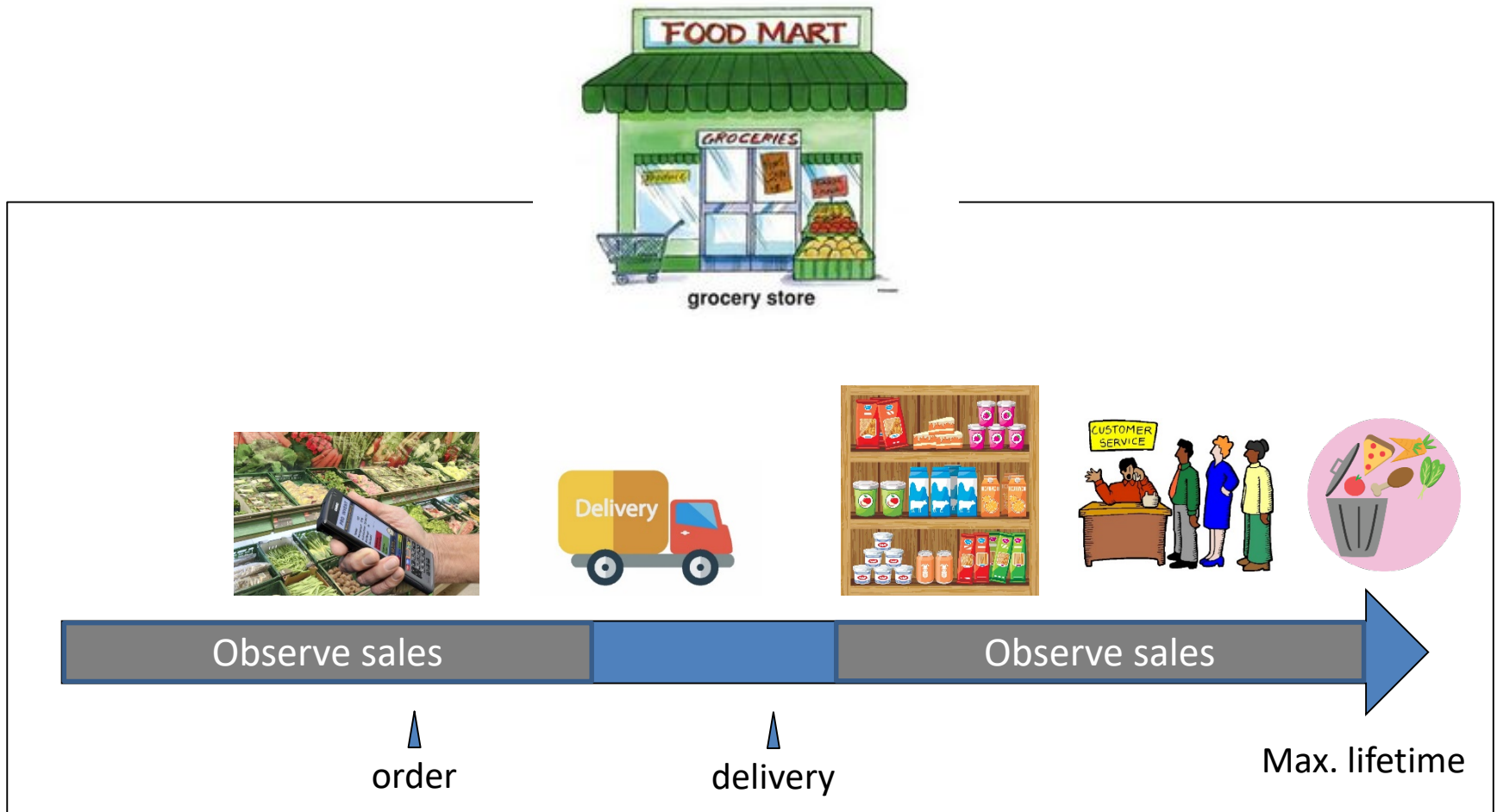
## Assumptions

- Products are perishable
- Order must be chosen before observing demand
- Demand is stochastic (uncertain)
- Order arrives before store opens
- Leftover inventory at the end of the season has to be discarded or can be sold at salvage value



Source: <http://cdn1.spiegel.de/images/image-1044144-galleryV9-jlvx-1044144.jpg>

# Sequence of events

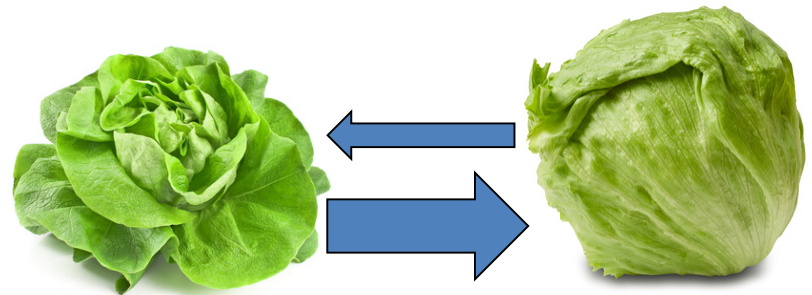
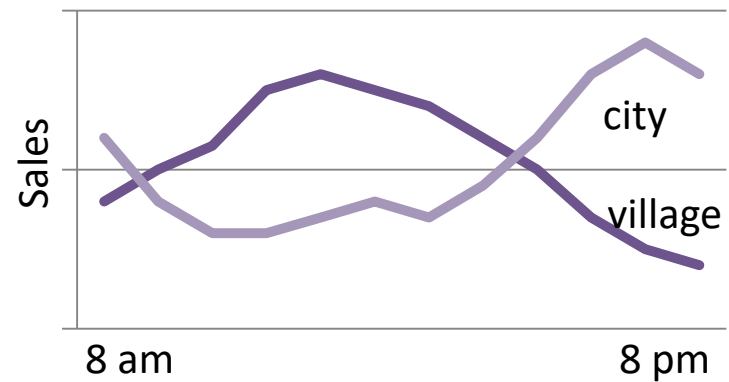


Sources: [http://www.redaktionsserver.de/CASIO/Produkt-Info\\_IT-G400-500\\_Zertifizierung/Download/CASIO\\_IT-G500\\_Bild03c.jpg](http://www.redaktionsserver.de/CASIO/Produkt-Info_IT-G400-500_Zertifizierung/Download/CASIO_IT-G500_Bild03c.jpg), <http://clipart-library.com>



# Data

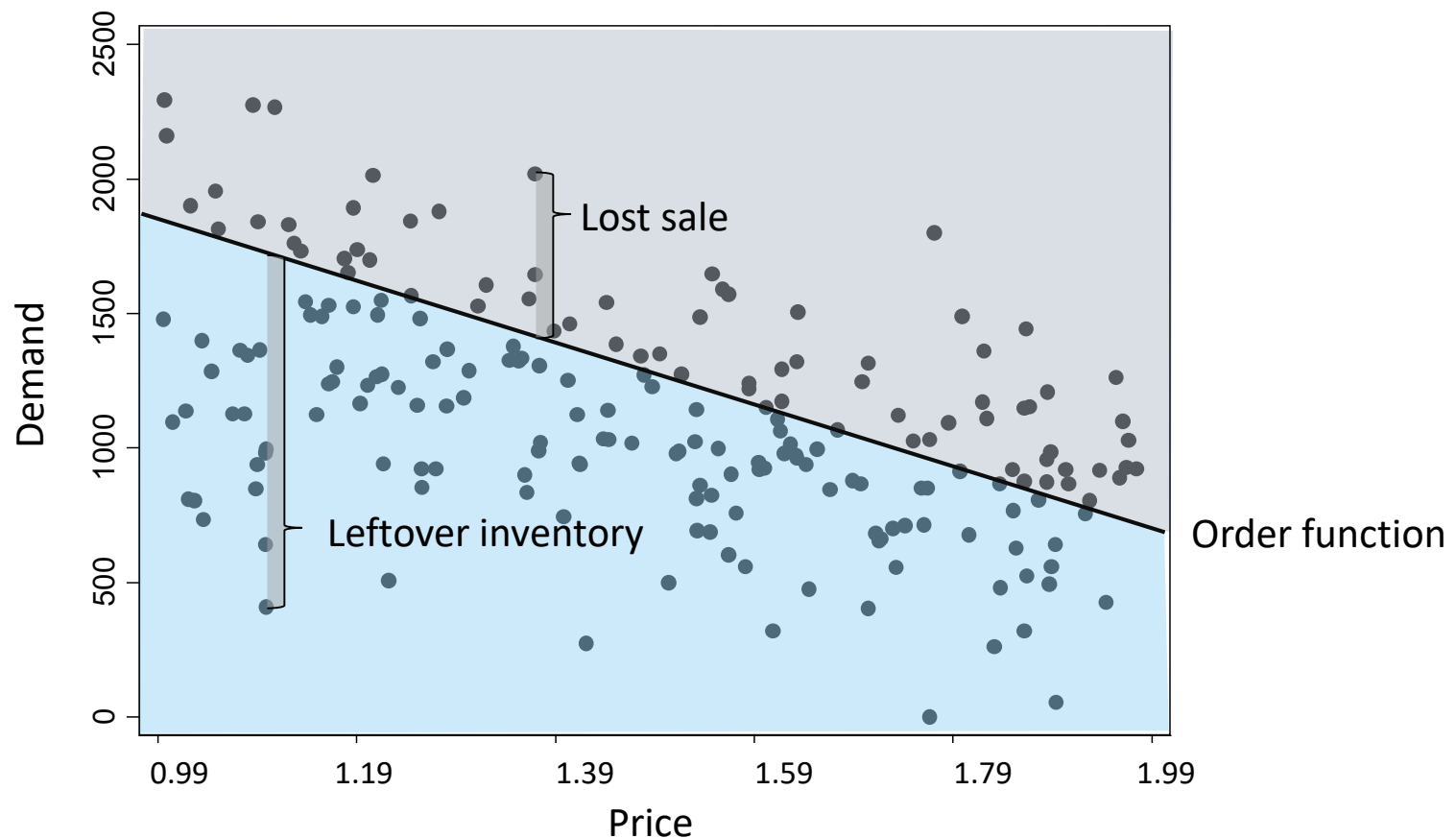
Hourly point-of-sale data from large European retail chain for 4 years and 64 stores



Sources: <http://de.fotolia.com/id/53590332>, <http://de.fotolia.com/id/26239414>, <http://de.fotolia.com/id/68937968>, <http://de.fotolia.com/id/62517211>

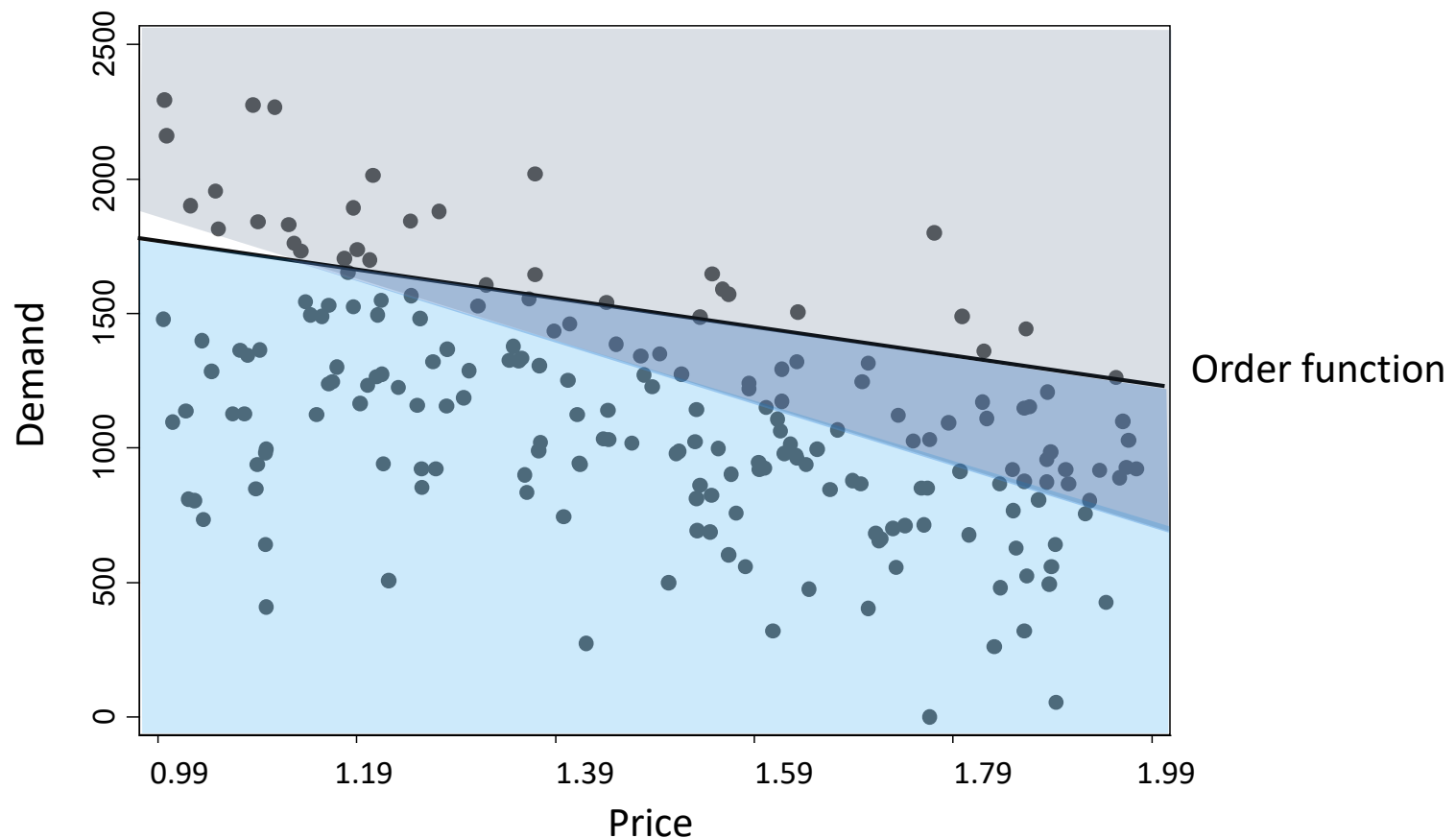
# The data-driven newsvendor: Integrated approach

- Integrate forecasting and inventory management
- Inventory level as linear function of external factors:

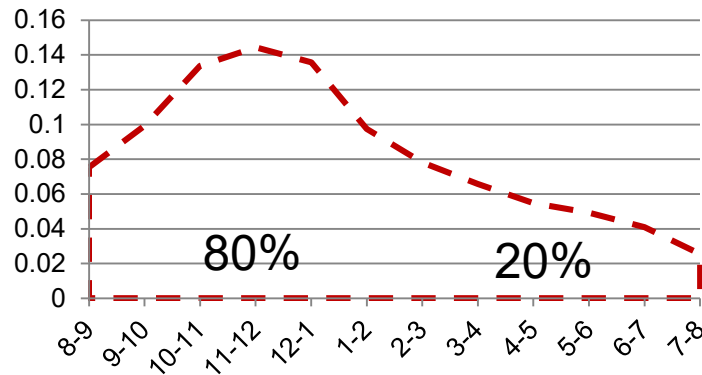


# The data-driven newsvendor: Integrated approach

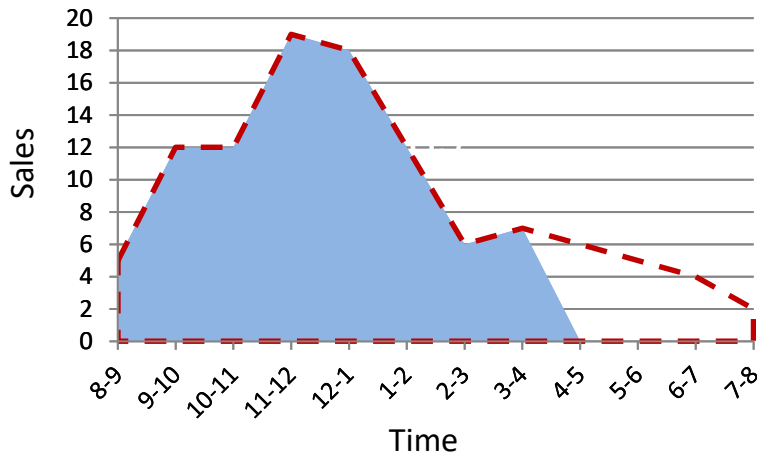
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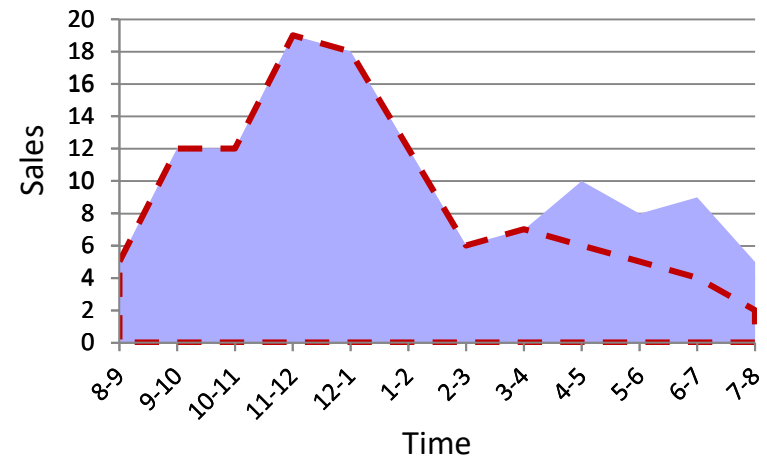
# Demand estimation in stockout situations



Unobservable lost sales

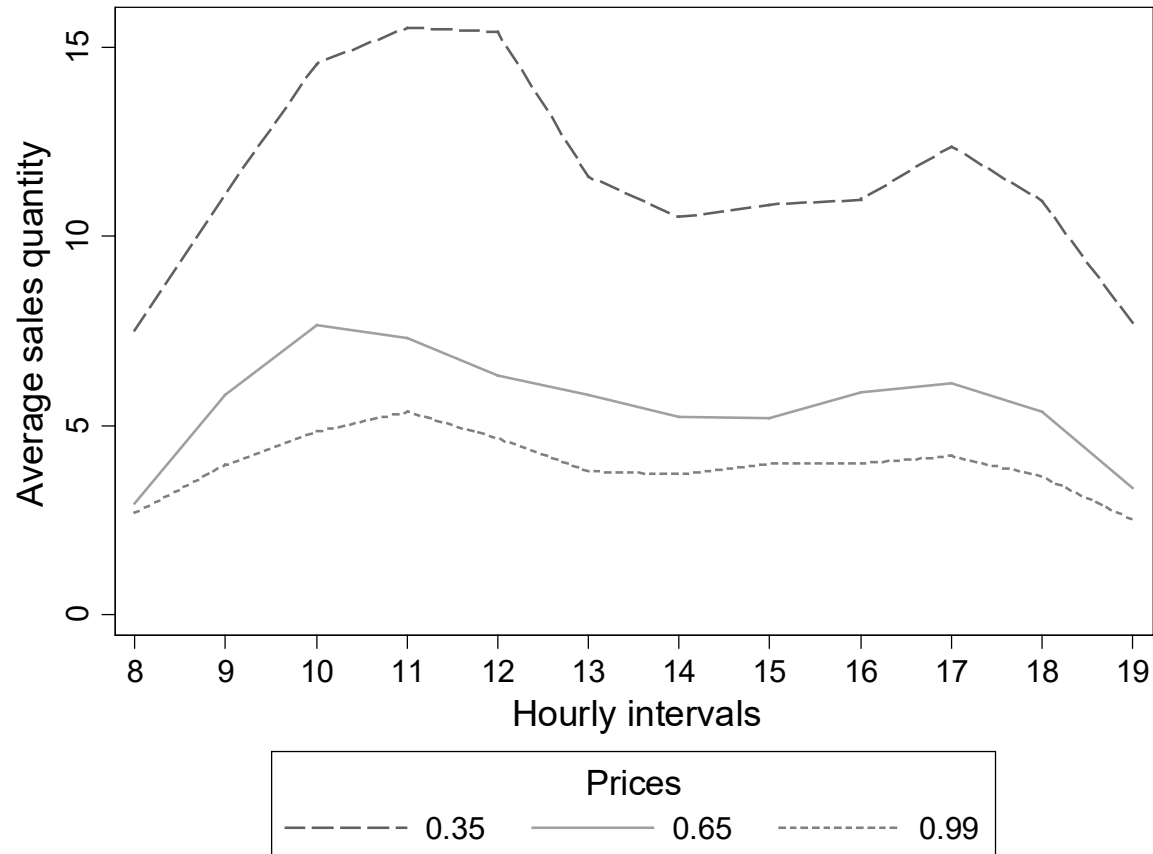


Substitution

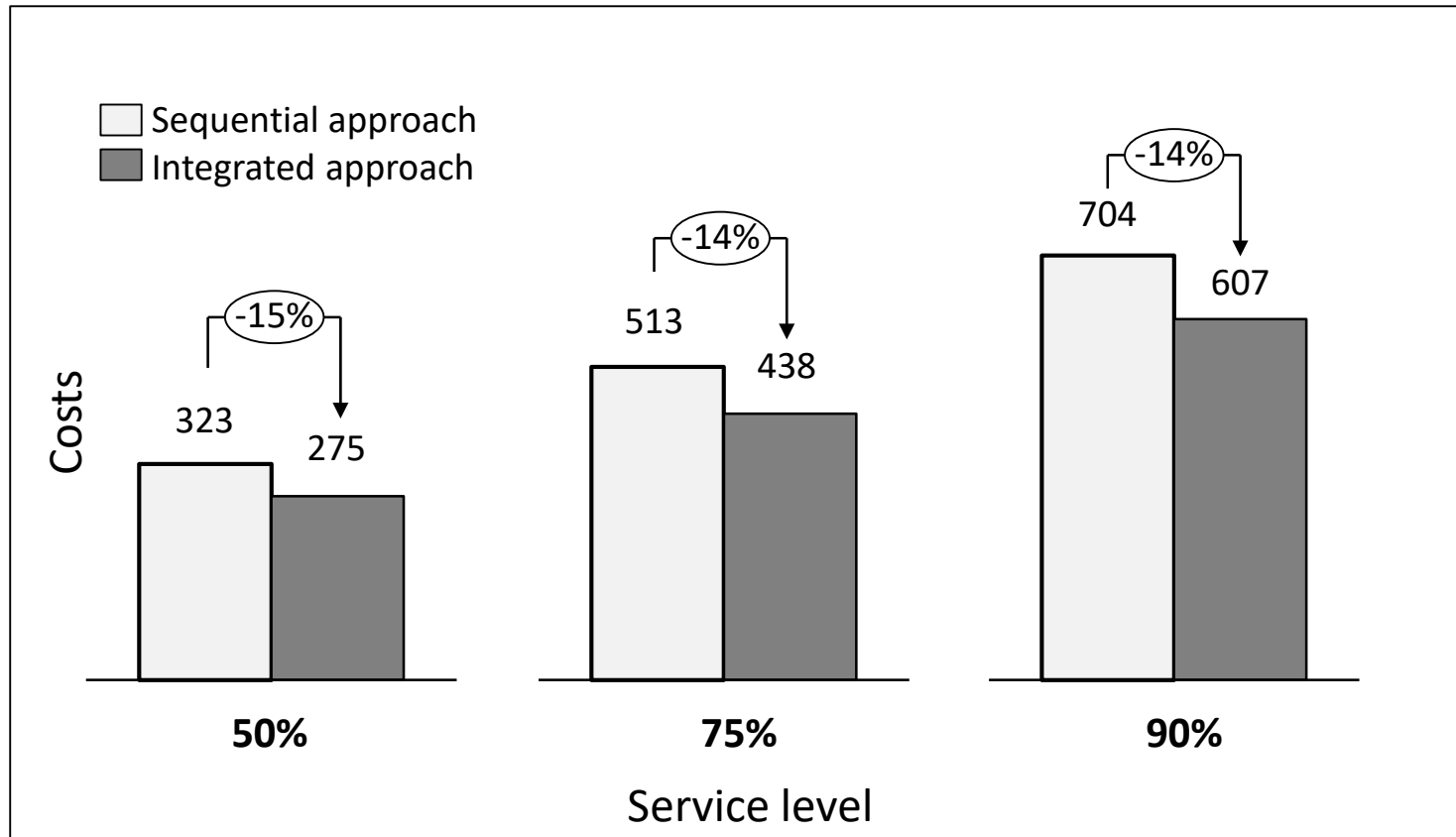




# Daily sales patterns



# Results



# Conclusion

## Summary

**Forecasting:** Point forecasts and demand variability should be taken into account.

**Demand:** If only sales are observed, it is important to estimate unobservable lost sales. Consider other factors influencing demand if possible.

**Inventory management:** The profit-maximizing order quantity often does not equal the point forecast. For example, if underage cost  $>$  overage cost, the order quantity is greater than expected demand.

## Other applications

**Capacity planning:** How much machine capacity should you make available?

**Contracts:** How many minutes should be included in your phone plan?

**Hospitals:** How much operating room time should you reserve for emergency surgeries?

**Consumption:** How many bottles of milk should you buy when grocery shopping?

# Thank you for your attention!

## Questions?

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## Additional references

Beutel, A.-L., Minner, S., 2012. *Safety stock planning under causal demand forecasting*, International Journal of Production Economics 140(2), 637-645.

Sachs, A.-L., Minner, S., 2014. *The Data-Driven Newsvendor with Censored Demand Observations*, International Journal of Production Economics 149, 28-36.