SUPPLY CHAIN CANADA

George Weston Ltd Centre for Sustainable Supply Chains

Schulich School of Business | YORK U

2022 Supply Chain Research Forum

Supply Chain Challenges: Practical Insights from Emerging Academic Research

Presented by ***Schulich School of Business*** *in partnership with* ***Supply Chain Canada.***

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"Unlocking the Potential of Digital Transformation with Digital Due Diligence and Uncertainty Modeling"

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Outline

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Supply Chain Problems of Kordsa

- Kordsa Inc. a global manufacturer of tire cords and reinforcement composites
- 12 production facilities in the U.S., Turkey, Brazil, Indonesia, and Thailand
- 3 child companies in the U.S. with 6 facilities
- Around 4500 employees
- Problems:
  - High inventory levels: Working Capital Reduction is a top priority
  - Backlogs and customer complains
  - ERP and digital systems do not meet Kordsa's expectations

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Diagnosis of Bottlenecks with Transformative Due Diligence

Simplicity

- Sketching out the most salient factors
- Simple enough to characterize the information, capital and operational flows in an organization

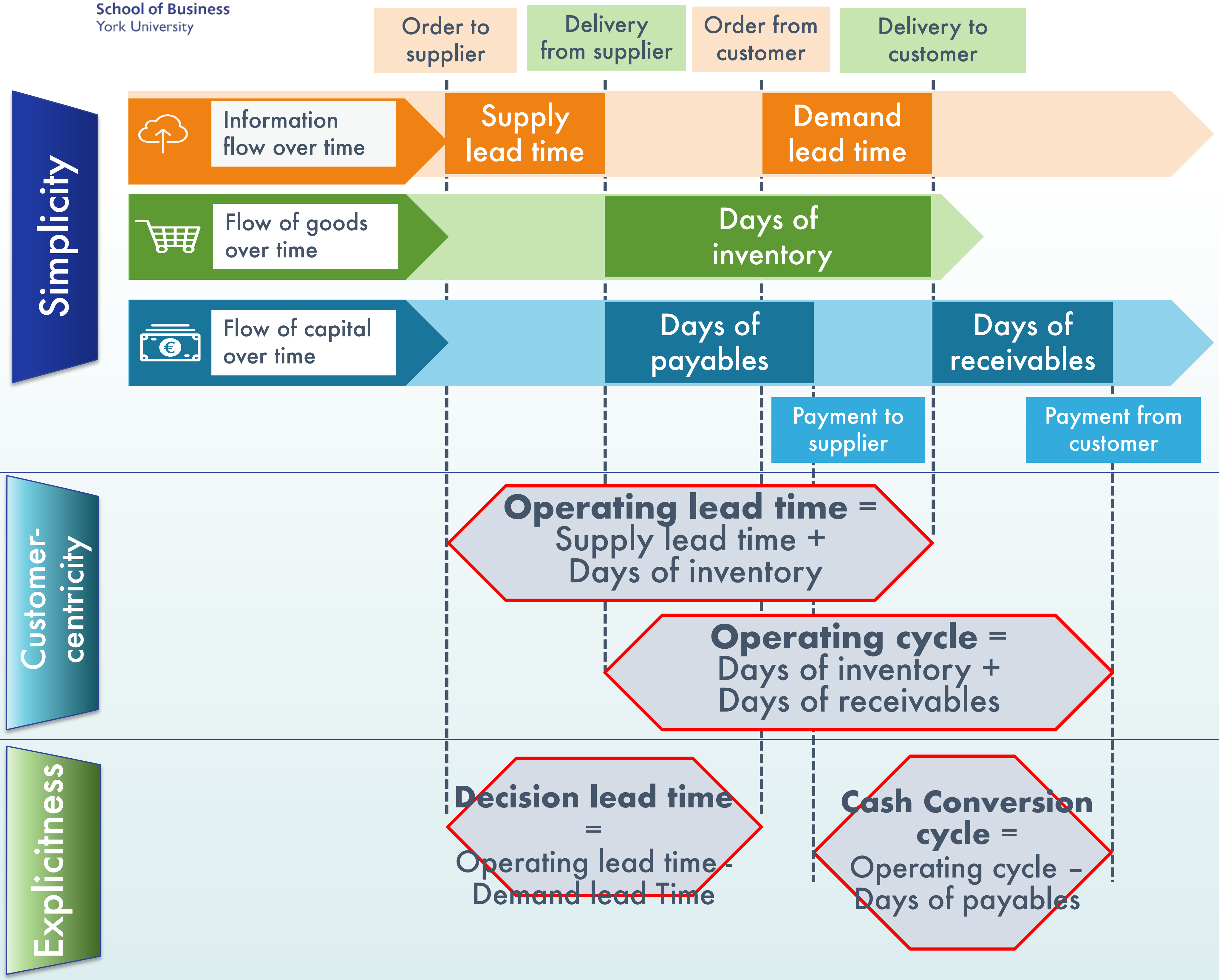
Customer-centricity

- Value proposition for customers
- Derivation of key indicators from the most salient factors

Explicitness

- Operational and financial risks
- Explicitly linked to the most salient factors

Example – Product Dashboard



DAYS	Max	Min	Avg.
Supply Lead Time	65	60	62
Demand Lead Time	42	14	22
Days of Inventory	95	40	43
Days of Payables	45	30	38
Days of Receivables	60	60	60

DAYS	Max	Min	Avg.
Operating Lead Time	155	102	122
Operating Cycle	152	100	113

DAYS	Max	Min	Avg.
Decision Lead Time	110	62	82
Cash Conversion Cycle	152	100	103

Supply Chain Challenge #1

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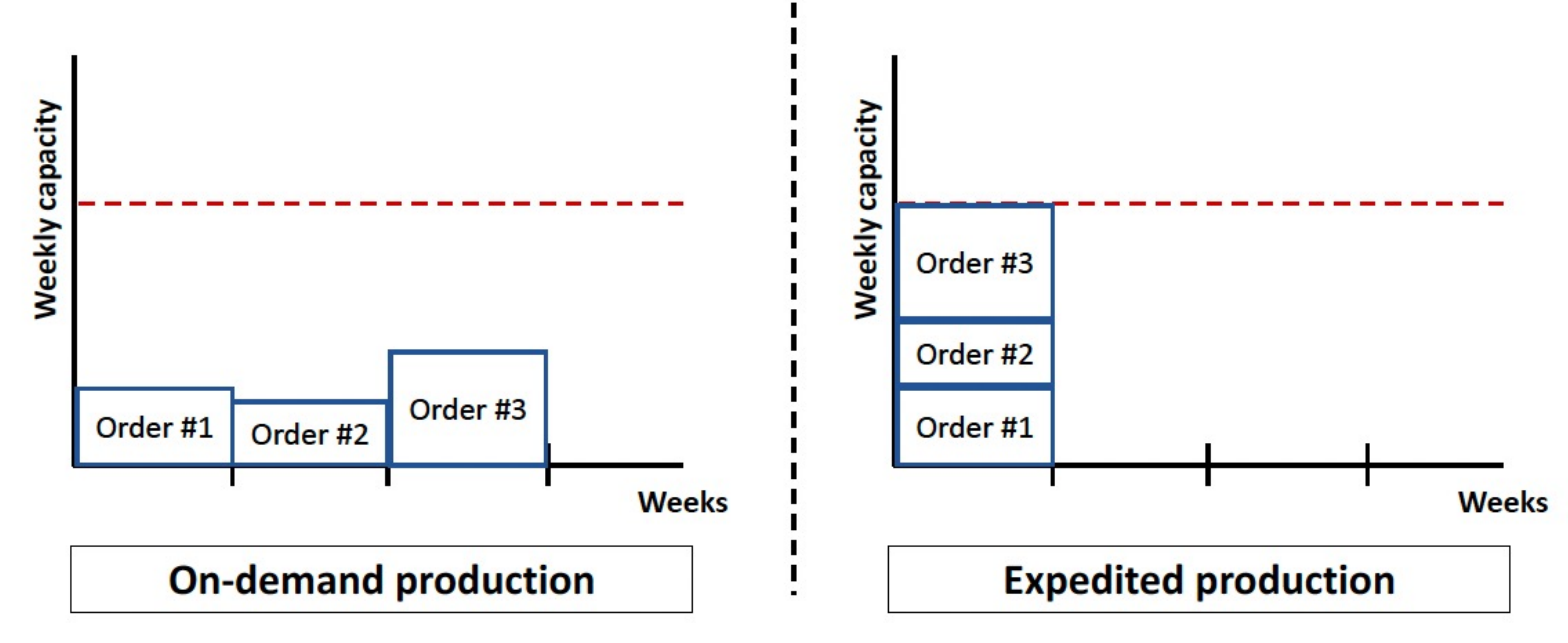
Kordsa receives bulky orders from its customers

1. The number of distinct orders in a week is uncertain
2. For each order, the quantity demanded is uncertain
3. For each order, demand lead time is uncertain

Uncertainty modeling represents demand as a combination of three uncertain parameters

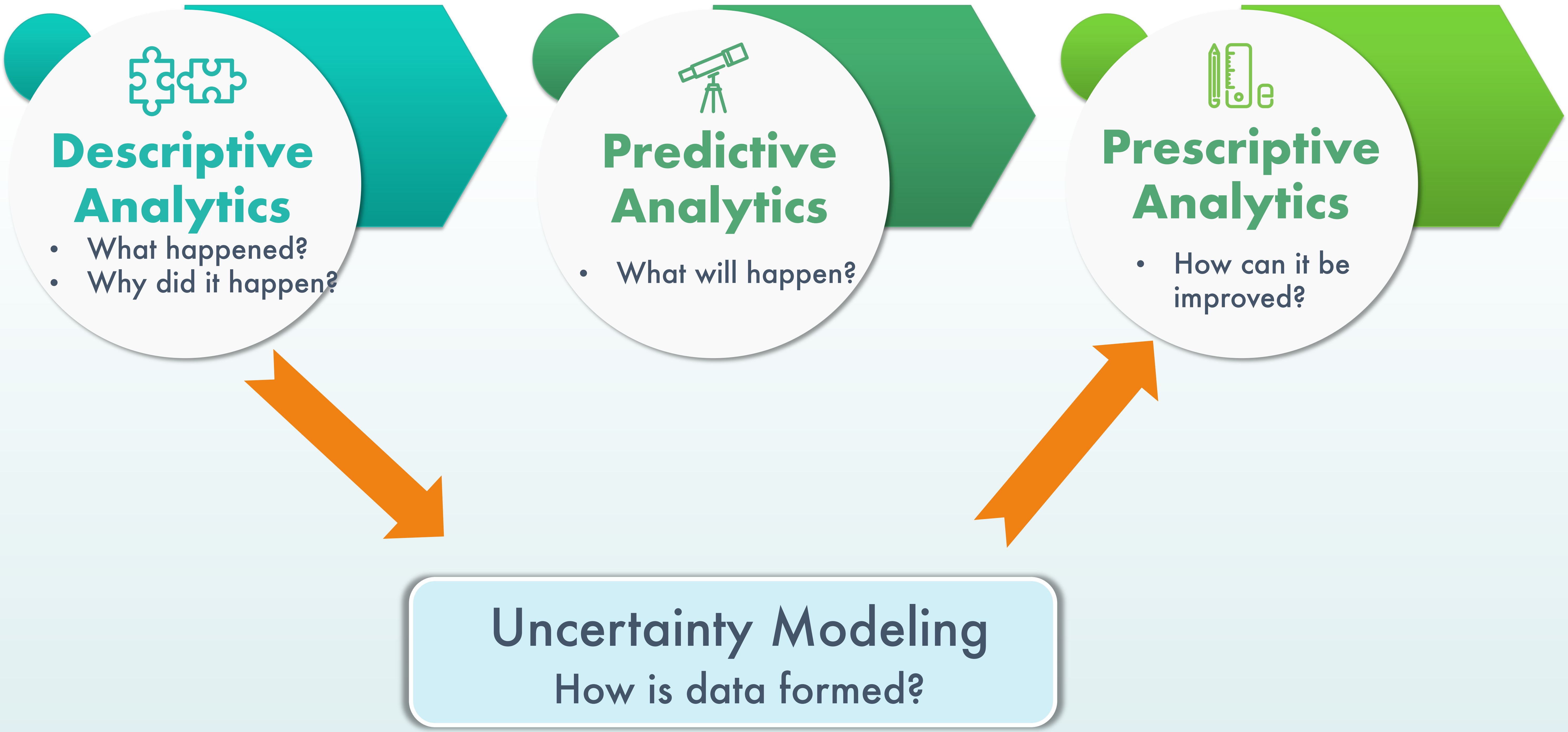
Supply Chain Challenge #2



Theoretical Background

- **Production Models**
  1. Hopp, Wallace J., and Mark L. Spearman. "To pull or not to pull: what is the question?" *Manufacturing & Service Operations Management* 6.2 (2004): 133-148.
  2. Suri, Rajan. 1998. Quick Response Manufacturing: A Companywide Approach to Reducing Lead Times. CRC Press, Portland, Oregon, USA.
  3. Baker, Kenneth R. 1993. Requirements planning. S. C. Graves, A. H. G. Rinnooy Kan, P. H. Zipkin, eds., Handbooks in Operations Research and Management Science, vol. 4, chap. 11. Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 571-627.
  4. Öhman, M., Hiltunen, M., Virtanen, K., & Holmström, J. (2021). Frontlog scheduling in aircraft line maintenance: From explorative solution design to theoretical insight into buffer management. *Journal of Operations Management*, *67*(2), 120-151.
- **Demand Management**
  1. Ozer, Ozalp, Wei Wei. 2004. Inventory control with limited capacity and advance demand information. Operations Research 52(6) 988-1000.
  2. Gallego, Guillermo, Ozalp Ozer. 2001. Integrating replenishment decisions with advance demand information. Management Science 47(10) 1344-1360.
  3. Karaesmen, Fikri. 2013. Value of advance demand information in production and inventory systems with shared resources. J. M. Smith, B. Tan, eds., Handbook of Stochastic Models in Manufacturing System Operations, chap. 5. Springer, New York, NY, USA, 139-165.

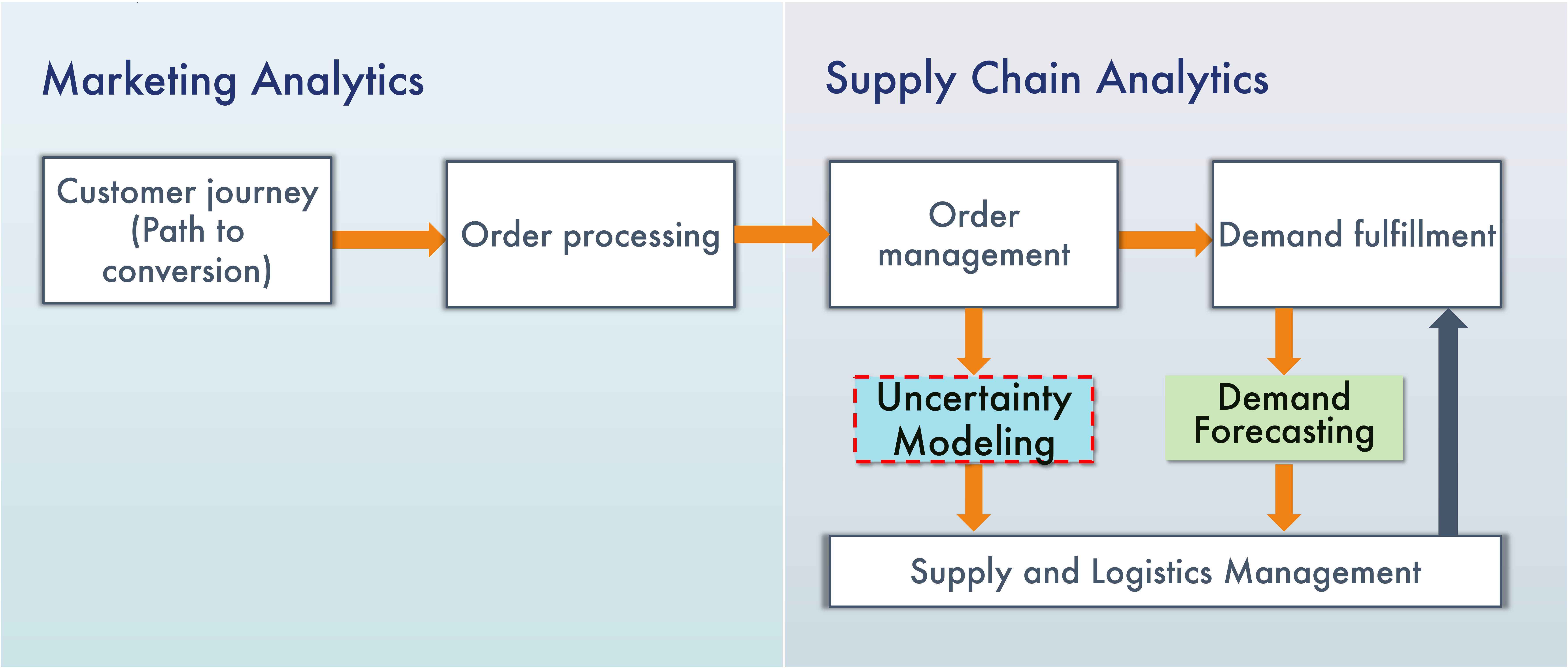
Uncertainty Modeling



Uncertainty Modeling vs Demand Forecasting

Uncertainty Modeling	Demand forecasting
• Reducing the decision bias • How are customer orders formed? • Order management datasets are used	• Reducing the forecast bias • What are the historical demand values and factors affecting the demand? • Demand fulfillment datasets are used

Uncertainty Modeling vs Demand Forecasting



Fast Fourier Transform

Additive demand (independent random variables)

- Demand = X + Y
- Characteristic function of demand is multiplication of the characteristic functions of X and Y

Multiplicative demand (independent random variables)

- Demand = X*Y
- ln(Demand) = ln(X)+ln(Y)
- Characteristic function of log-demand is multiplication of the characteristic functions of ln(X) and ln(Y)

Prescriptive analytics with the Fast Fourier Transform

- What should we be able to compute for optimization under uncertainty?
  - Cumulative demand
  - Partial integral

Analytical Approach

- Inputs
  - Advance demand
  - Inventory level
  - Capacity
  - Target service level
- Output
  - Production mode (on-demand vs expedited)
- Uncertainty model
  - Multiplicative: Urgent orders arrive according to a compound Poisson process and quantity demanded is proportional to advance order

$$\ln(\gamma_{l_p}) = \ln(\gamma_t) - \lambda(e^{\tau+\zeta^2/2} - 1)(l_p - t) + \sum_{i=N_t}^{N_{l_p}} \ln(Y_i)$$

$$\phi_{\ln(\gamma_{l_p})}(\omega) = \gamma_0^{i\omega} e^{-\lambda l_p (e^{\tau+\zeta^2/2}-1)i\omega} e^{\lambda l_p [e^{(\tau i\omega - \zeta^2\omega^2/2)}-1]}$$

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Analytical Approach

Proposition 1. *The probability term (3) can be formulated as a function of the characteristic function:*

$$Pr(K \times (l_p - l_f - 1) > \sum_{i \in \mathcal{S}} \sum_{r=j+l_f+2}^{j+l_p} D_{ir}) = \frac{e^{-\alpha z}}{\pi} \int_0^{+\infty} e^{-i\omega x_j} \psi(\omega) \partial\omega, \tag{10}$$

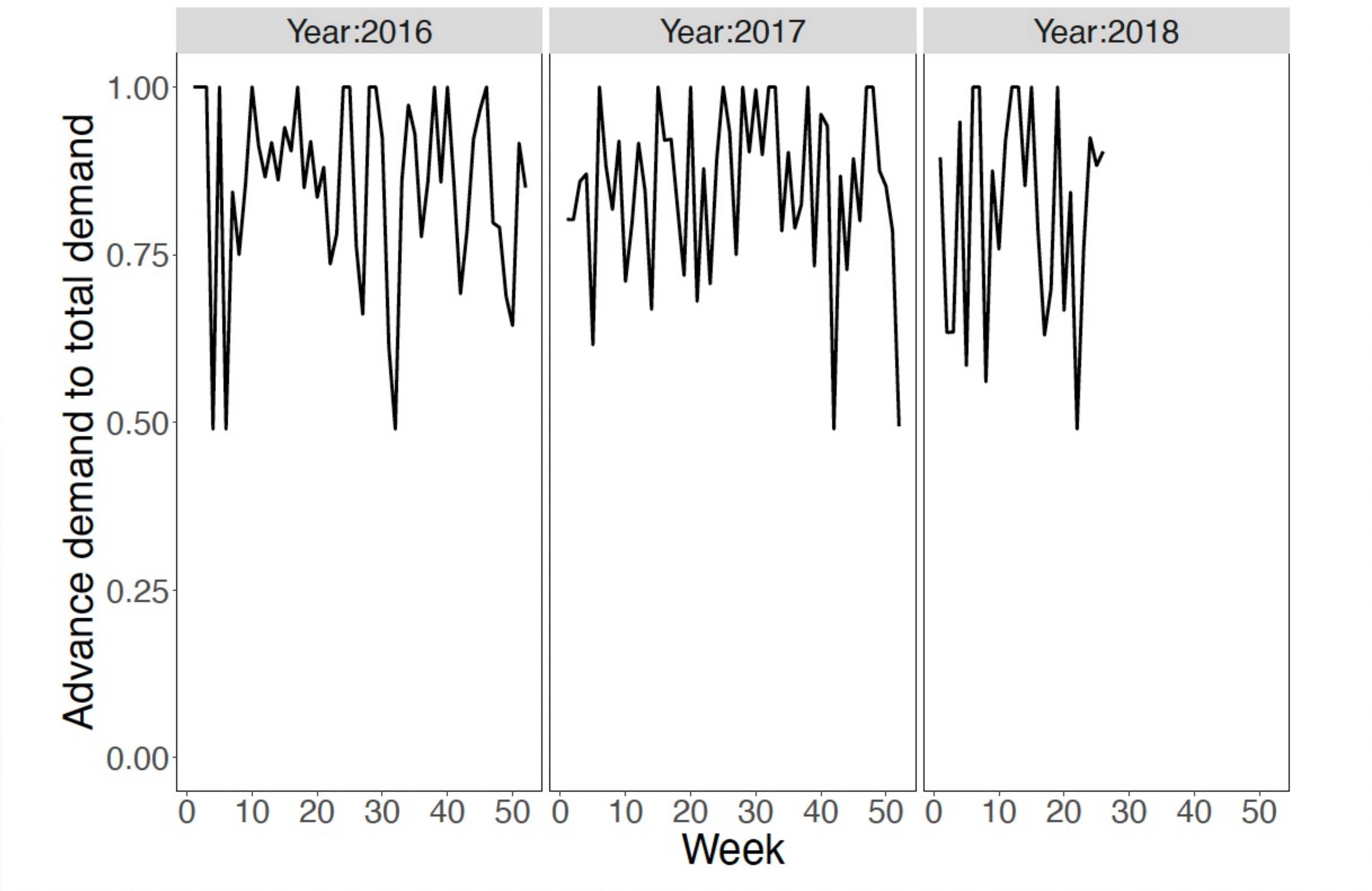
where

$$x_j = \ln(K \times (l_p - l_f - 1)), \tag{11}$$

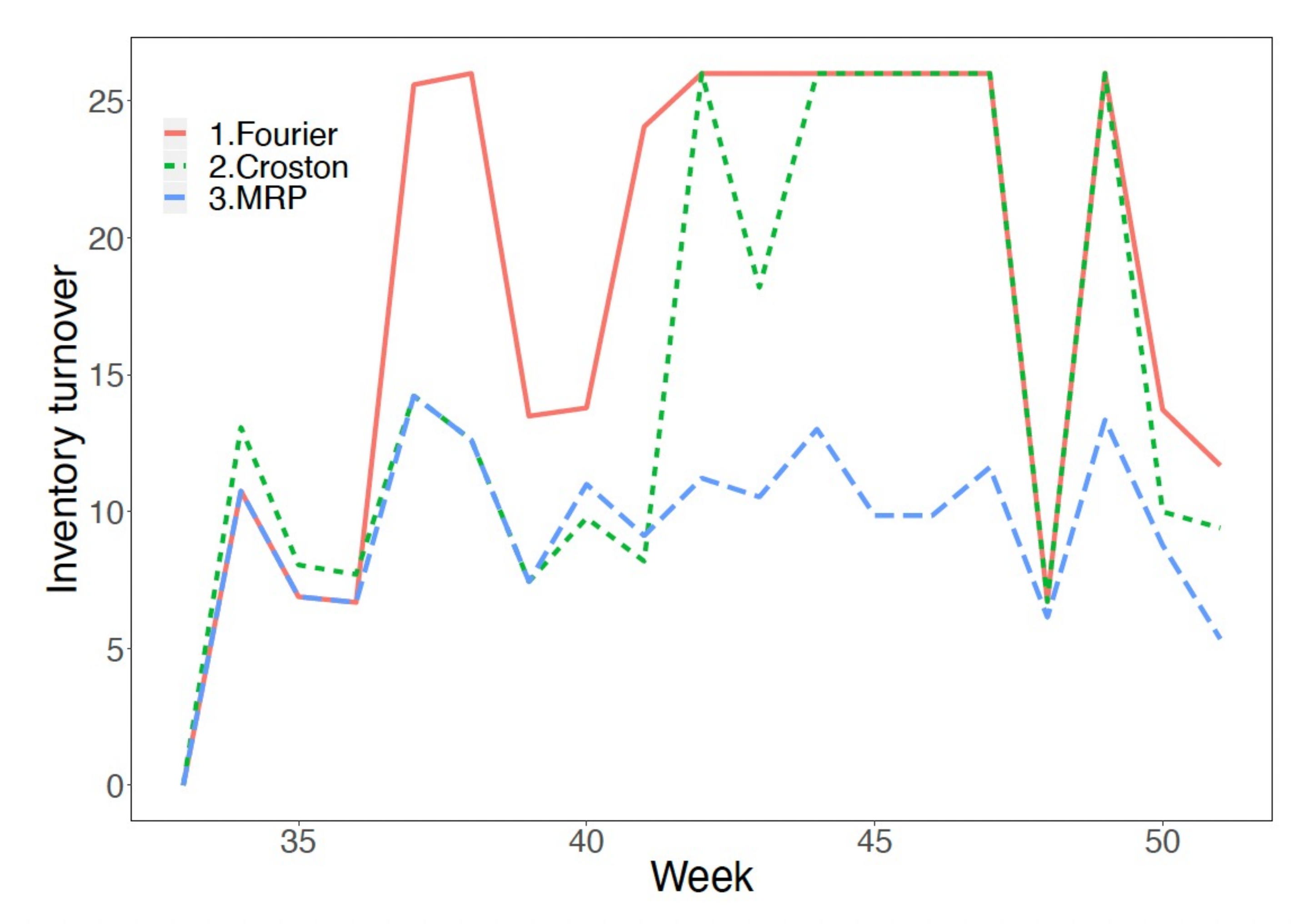
$$\psi(\omega) = \frac{i\phi_{\ln(\gamma_{l_p})}(\omega - \alpha i)}{\omega - \alpha i}, \tag{12}$$

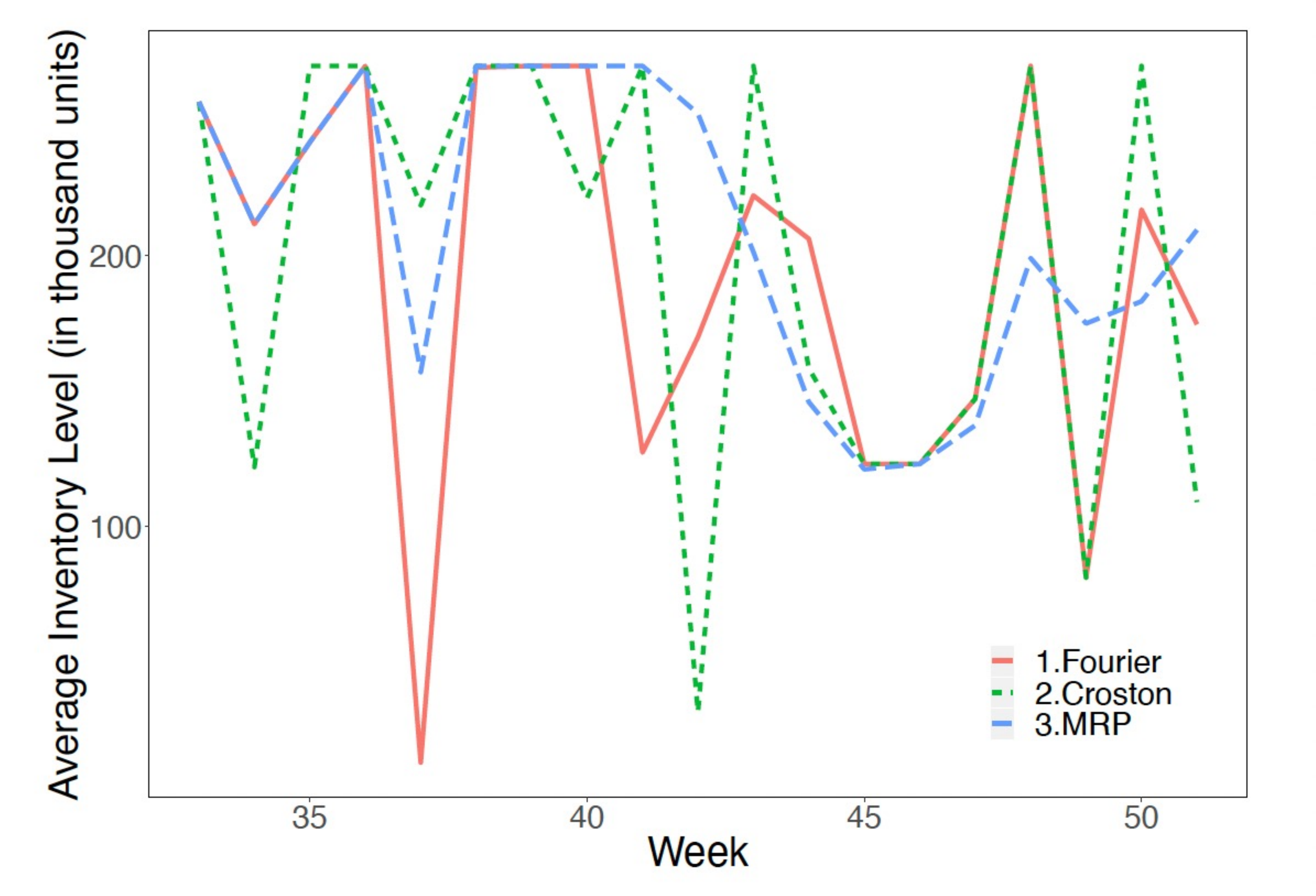
and $i = \sqrt{-1}$ *and* α *is the damping factor that ensures the square-integration of the integral.*

Model Assessment (Data Description)



Model Assessment (Results)





Example: Decision Dashboard

		June 2022 (current)	July 2022	August 2022
Inventory	Opt. Inv.	14,000	19,000	24,000
	Planned:	12,000	21,000	18,000
	Lost:	3,000 kg	5,000 kg	9,800 kg
	Excess:	1,000 kg	2,000 kg	1,200 kg
	Profit:	$1.32 M	$1.88 M	$1.67 M
Prod'n	Available:	4,000 kg	12,000 kg	21,000 kg
	Production:	14,000 kg (risk adjusted)	34,000 kg (risk adjusted)	41,000 kg (risk adjusted)
Supply	Raw material:	B22C20 polypropylene ☑	B22C20 polypropylene ☑	B22C20 polypropylene ☑
	Available:	14,000	14,000	15,000
	Order:	28,000 kg (risk adjusted)	70,000 kg (risk adjusted)	82,000 kg (risk adjusted)
Demand	Expected Demand:	6,000 kg	25,000 kg	44,000 kg
	Min:	2,000 kg	20,000 kg	36,000 kg
	Max:	10,000 kg	32,000 kg	54,000 kg

Concluding Remarks

- Do not aggregate your data. Try to understand where the uncertainty comes from!

The New Stack

AI Development Needs to Focus More on Data, Less on Models

... artificial intelligence needs to be less focused on building models and more focused around data, said Andrew Ng in his talk at Insight...

1 month ago

- Start digital transformation with due diligence!

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Related Research

- Biçer, I. and Tarakci, M., 2021. Managing Capacity Utilization with Advance Orders. *Available at SSRN 3972463*.
- Biçer, I., Tarakci, M. and Kuzu, A., 2022. Using uncertainty modeling to predict demand. Harvard Business Review
- Biçer, I., 2022. Securing the upside of digital transformation before implementation: Keeping it simple, customer centric and explicit. California Management Review
- Biçer, I., Hagspiel, V. and De Treville, S., 2018. Valuing supply-chain responsiveness under demand jumps. *Journal of Operations Management*, *61*, pp.46-67.

For more information:
https://www.yorku.ca/research/areas/supplychainanalytics/

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Questions?

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Thank you

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