Managing Perishables with Stochastic Supply

By Iyer N. V. Parameshwaran
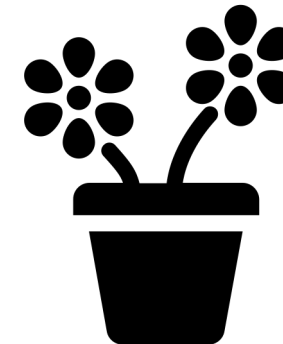
Advisor: Dr. Nima Kazemi
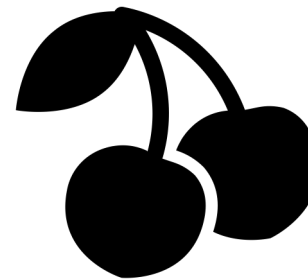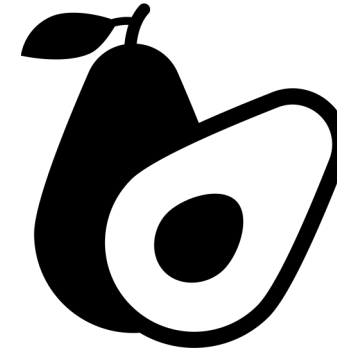
MiT | Supply Chain MANAGEMENT

Research Objective

Demand Surge

Perishable Commodity

Supply Variability

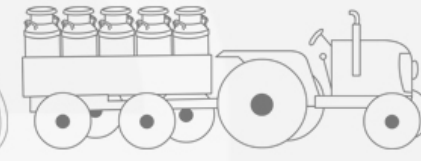Problem Statement · Literature Review · Methodology & Model · Case Study · Results & Conclusion

Demand-Supply Profile

Supply

Demand

Supply Drop

Demand Surge
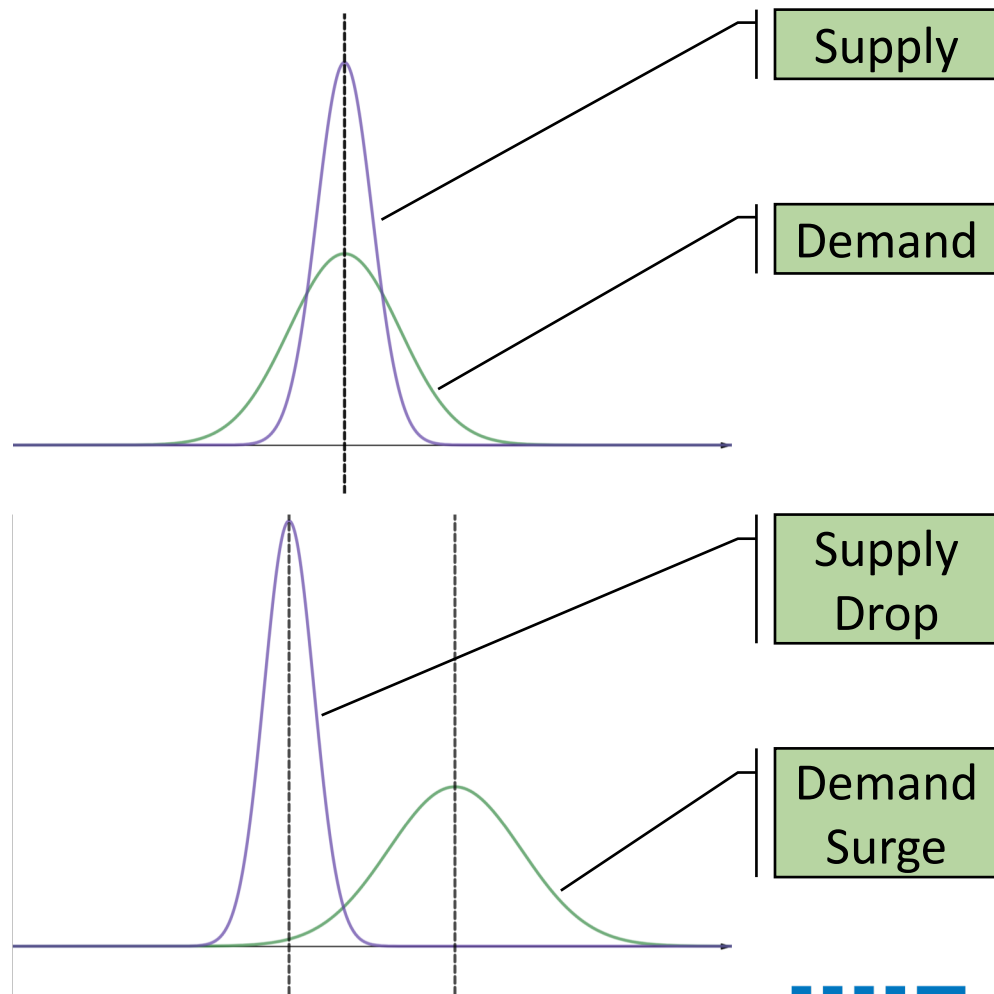
Summary of Current Research

- Focus on reducing spoilage of perishables

- Supply disruptions vs uncertainty

- Surge management via information distribution
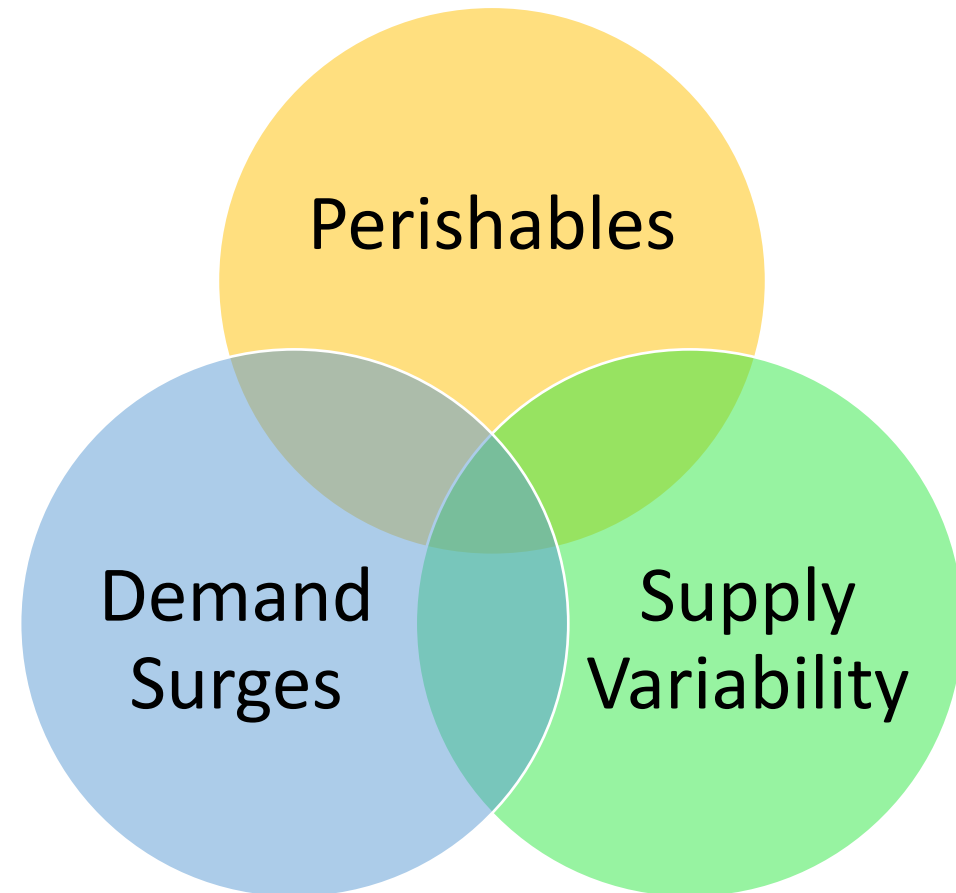
Research Sponsor

Leading private dairy company in Eastern India

'Ethical Milk Sourcing' initiative to attract and retain supplier loyalty

Focus on data management policy since inception

Methodology

Qualitative Analysis: Interviews

Quantitative Analysis: Modeling

Solution Validation: Simulation

Stakeholder Feedback: Feasibility

Supply Chain
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Supply Chain Flow & Timelines
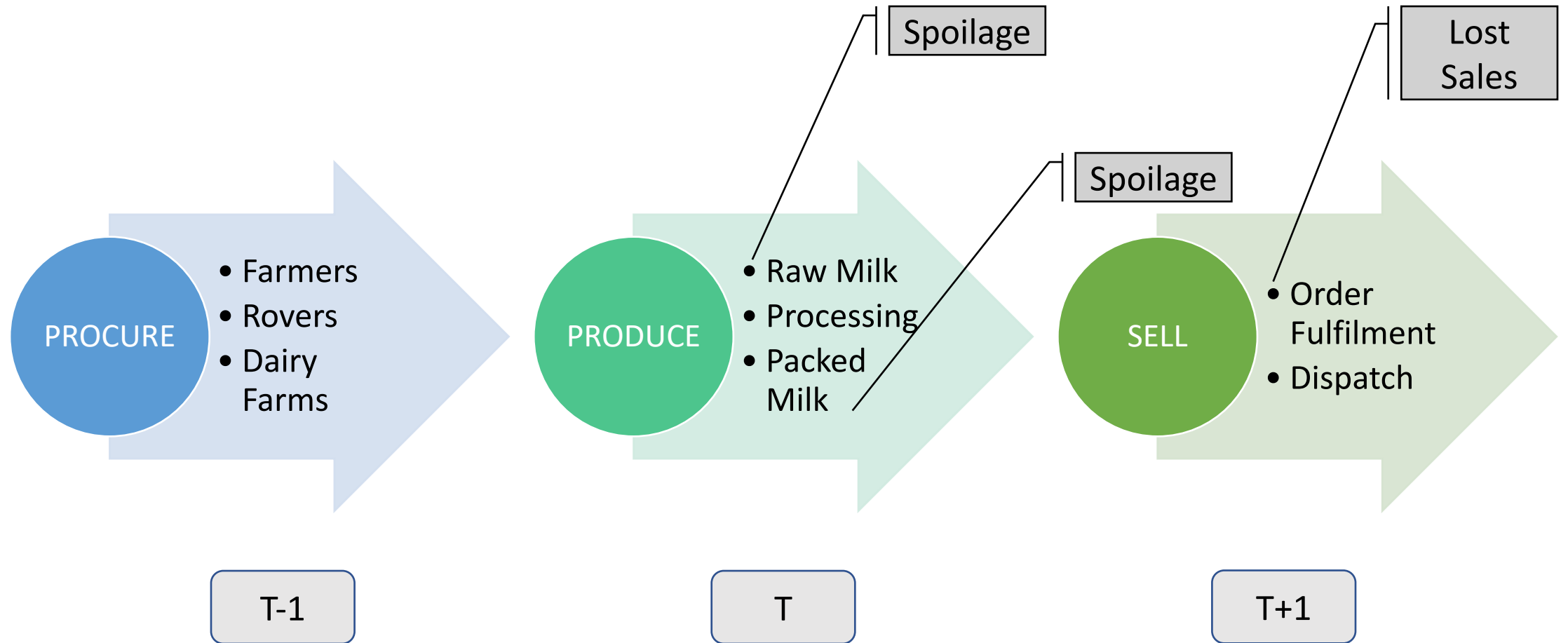
Time Series for Supply-Production-Demand

Time Period	Supply	Raw Material	Production	Finished Goods	Demand
…	…				
99	500	…	…	…	
100	495	500	500	500	…
101	505	495	495	495	505
102	…	505	505	505	500
103		…	…	…	495
…					…

Stochastic LP: Normal Approximation
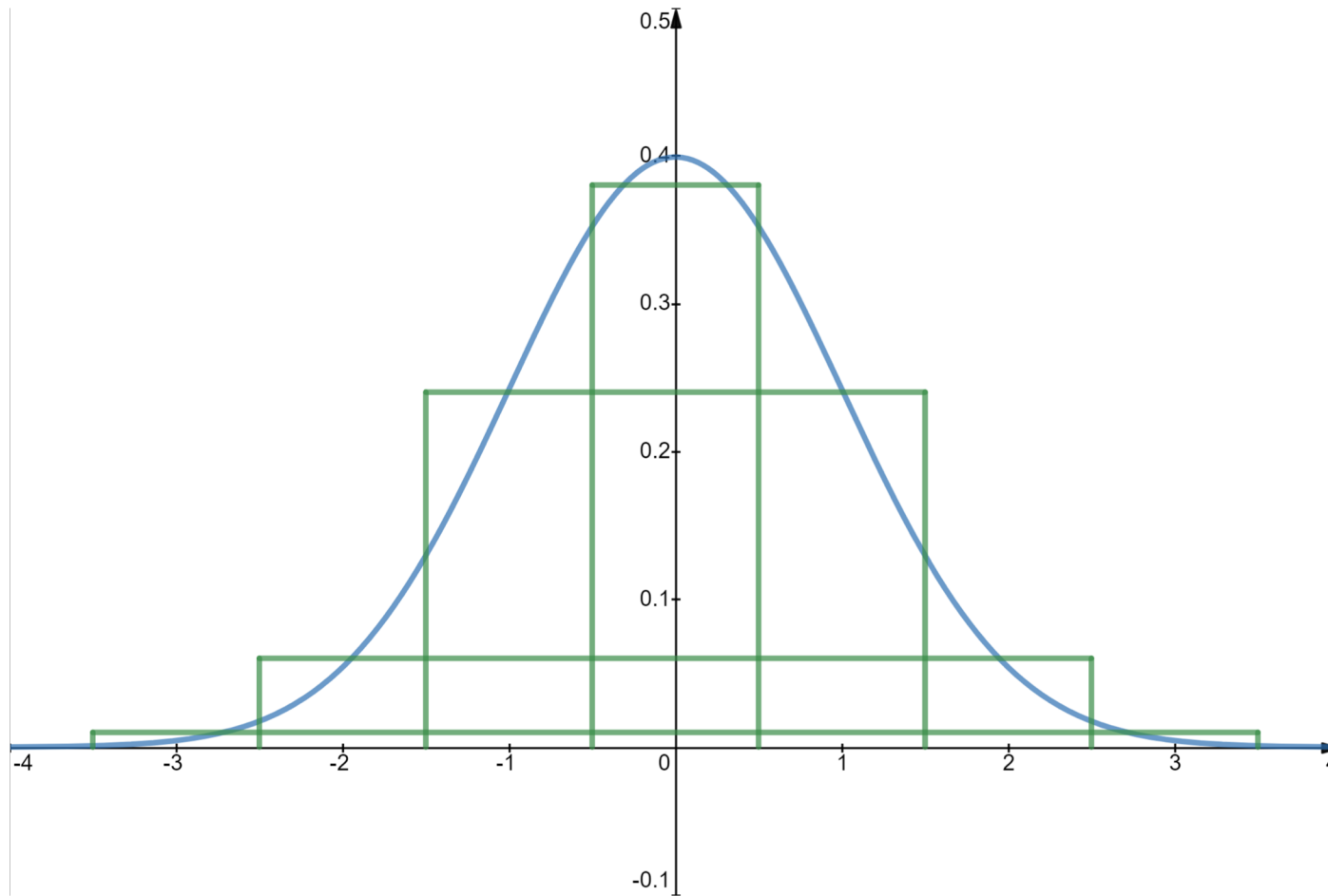
Scenario	Probability	Scaling Factor
1	0.01	1-3*CV
2	0.06	1-2*CV
3	0.24	1-1*CV
4	0.38	1
5	0.24	1+1*CV
6	0.06	1+2*CV
7	0.01	1+3*CV

Supply Target Recommendation

Time Series without Festival Days

Days	Default	Optimal	Practical
-	100.000	105.263	105.263
-	100.000	105.263	105.263
Reg	100.000	105.263	105.263
Reg	100.000	105.263	105.263
Reg	100.000	105.263	105.263
Reg	100.000	105.263	105.263
Reg	100.000	105.263	105.263
Reg	-	-	-
Reg	-	-	-
Total Profit	3241.38	3758.19	3758.19
Avg Profit	463.06	536.88	536.88

Time Series with Festival Day

Days	Default	Optimal	Practical
-	100.000	105.263	110.000
-	100.000	105.263	110.000
Reg	100.000	126.316	110.000
Reg	100.000	105.263	110.000
Spl	100.000	116.959	110.000
Reg	100.000	105.263	110.000
Reg	100.000	105.263	110.000
Reg	-	-	-
Reg	-	-	-
Total Profit	2257.81	3865.56	3358.81
Avg Profit	322.54	552.22	479.83

Research Contribution

Mathematical model to recommend supply targets to manage demand-supply mismatch

Three-stage stochastic programming for sourcing, production and dispatch decisions

Scalable & extendable solution using open source options (Python & Google-OR Tools)
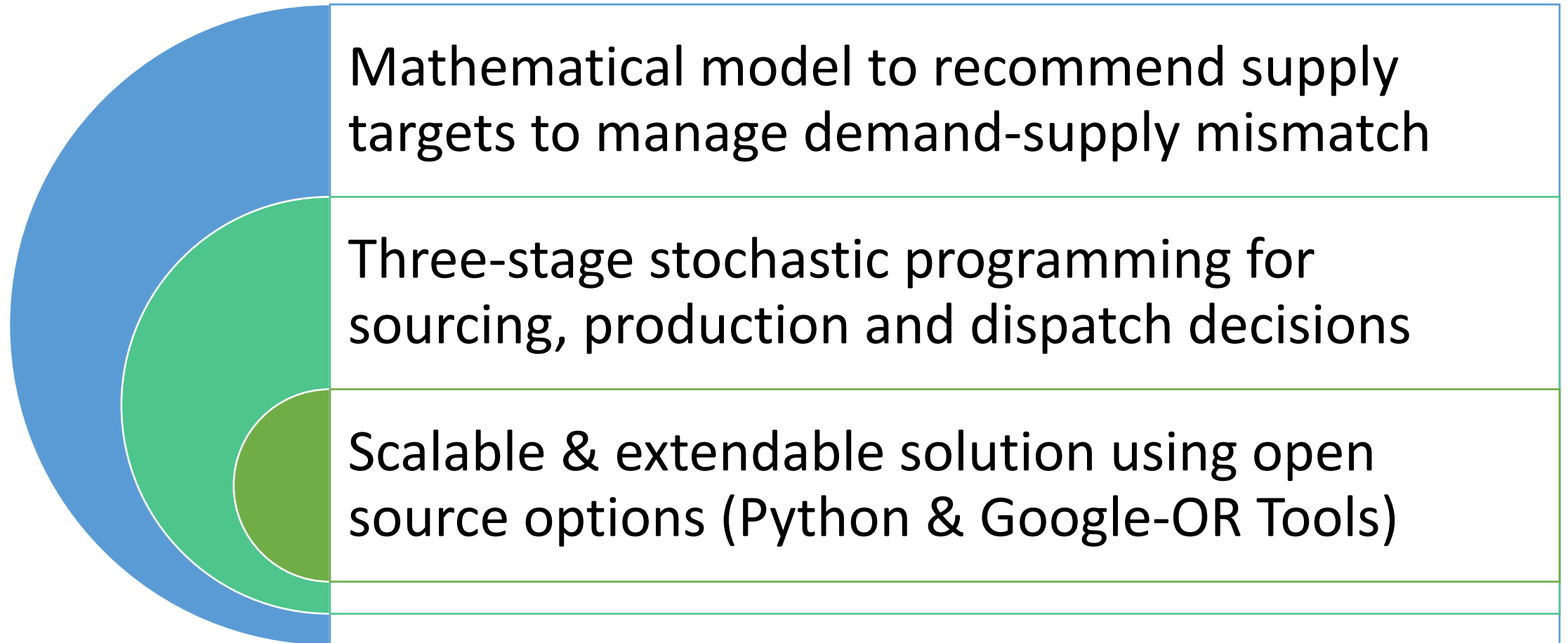
Summary

- 3-stage stochastic optimization model is the right fit

- Ability to set supply targets at time-period level is preferable

- Easy to extend and customize the solution to your context

Questions?

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Backup Slides

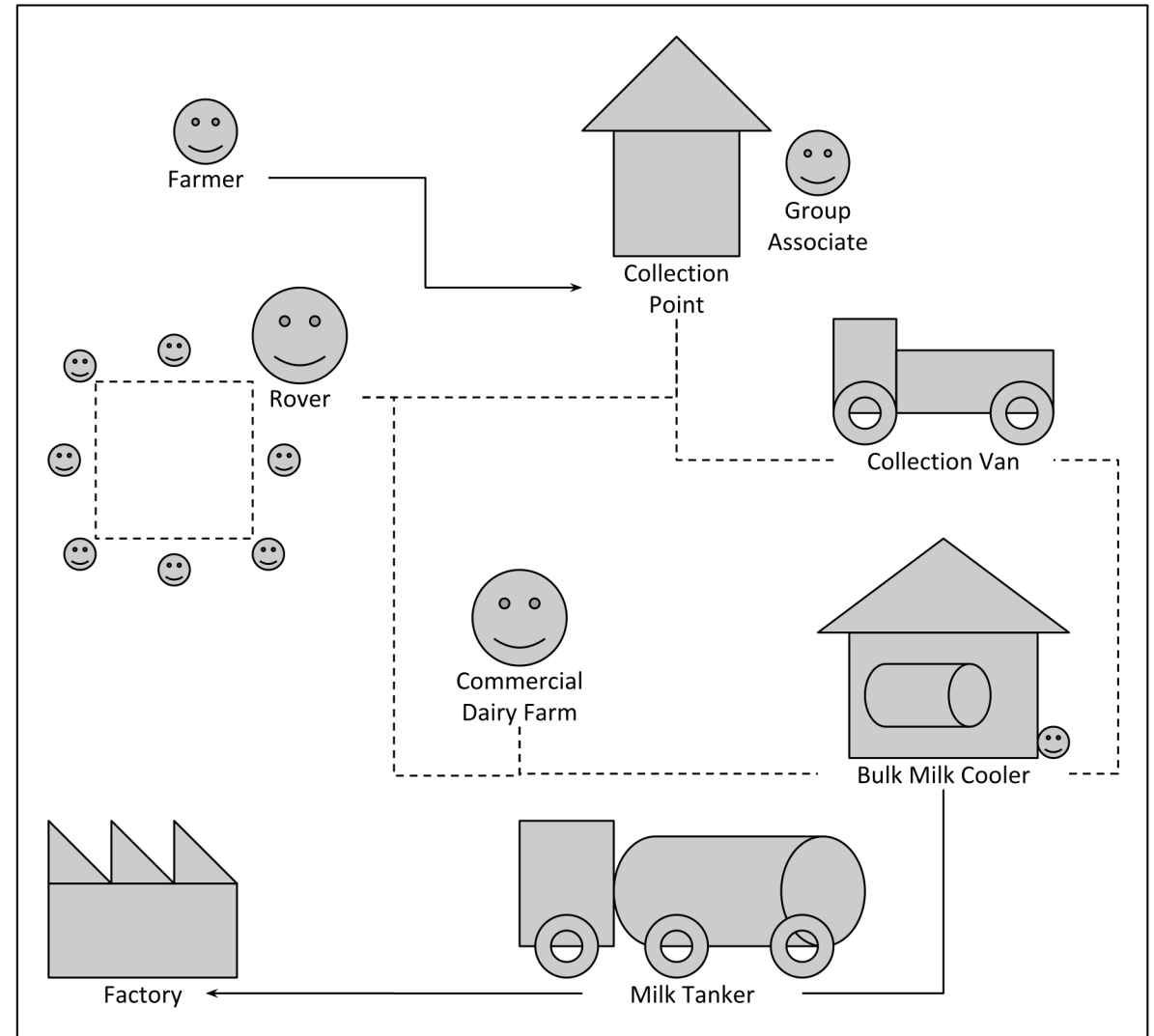Do not use unless necessary!!!

Sourcing Process

Primary sources of supply

Role of Rovers

Collection Point

Bulk Milk Cooler

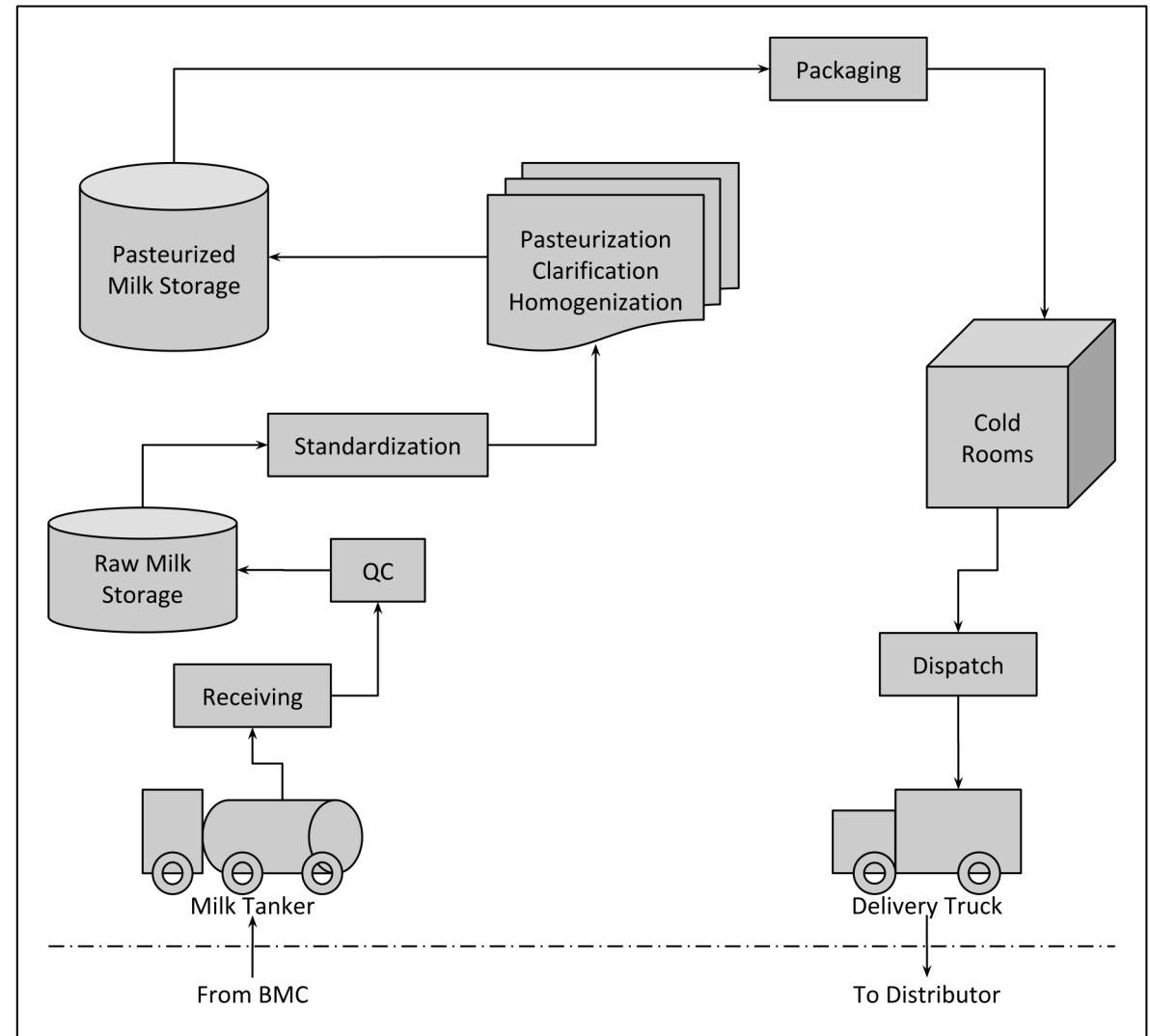Raw Milk Transportation

Production Process

Intake

Storage

Transformation

Packing

Dispatch

Optimization Model

Symbol	Explanation
SETS	
T	Set of time periods within the time series, indexed by t
I	Set of occurrences of a discrete probability of supply, indexed by i
J	Set of occurrences of a discrete probability of demand, indexed by j
PARAMETERS	
ΔD	Time periods between production and demand realization
ΔS	Time periods between supply realization and production
D	Demand expected per time period for the entire time series
C_1	The incremental cost of procurement of per unit of raw material
C_2	The incremental cost of production of per unit of finished goods
C_3	The incremental cost of selling per unit of finished goods to fulfill the demand
G_1	Salvage value per unit of excess raw material
G_2	Salvage value per unit of excess finished goods
P	Selling price realized for any unit sold
B	Shortage cost of unfulfilled demand per unit
p_i^S	Probability of the occurrence of a specific value of supply
δ_i^S	Scaling factor for the specific value of supply
p_j^D	Probability of the occurrence of a specific value of demand
δ_j^D	Scaling factor for the specific value of demand
Y_t	Binary value representing whether a specific time period has a simultaneous demand surge and supply shortage
α^D	The incremental surge in demand (+ve) during the relevant time period
α^S	The decremental wane in supply (-ve) during the relevant time period
RANDOM VARIABLES	
D_t	Demand realized for time period t
S_t	Supply realized for time period t
π_t	Profit for time period t
S_t^i	The specific value of supply for time period t
D_t^j	The specific value of demand for time period t
DECISION VARIABLES	
$S_t^{\sim}$	Supply target for time period t
$S^{\sim}$	Supply target per time period for the entire time series
ρ_t	Production realized for time period t
$\rho_t(S_{t-\Delta S}^i)$	Production realized for time period t as a function of supply realized
φ_t	The sale realized for time period t

$$max \sum_{t\in T}\sum_{i\in I} p_i^S * \sum_{j\in J} p_j^D * \pi_t$$

$$s.t.\, \pi_t = P * \varphi_t - \left(C_1 * S_{t-\Delta S}^i + C_2 * \rho_t(S_{t-\Delta S}^i) + C_3 * \varphi_t\right) \qquad \forall\, t \in T, i \in I, j \in J$$

$$+ \left(G_1 * \left(S_{t-\Delta S}^i - \rho_t(S_{t-\Delta S}^i)\right) + G_2\right.$$

$$\left. * \left(\rho_t(S_{t-\Delta S}^i) - \varphi_t\right)\right) - B * \left(D_{t+\Delta D}^j - \varphi_t\right)$$

$$\varphi_t \le \rho_t(S_{t-\Delta S}^i) \qquad \forall\, t \in T, i \in I$$

$$\varphi_t \le D_{t+\Delta D}^j \qquad \forall\, t \in T, i \in I$$

$$\rho_t(S_{t-\Delta S}^i) \le S_{t-\Delta S}^i \qquad \forall\, t \in T, i \in I$$

$$D_t^j = D * \delta_j^D * (1 + Y_t * \alpha^D) \qquad \forall\, t \in T, j \in J$$

$$S_t^i = S_t^{\sim} * \delta_i^S * (1 + Y_t * \alpha^S) \text{ OR} \qquad \forall\, t \in T, i \in I$$

$$S_t^i = S^{\sim} * \delta_i^S * (1 + Y_t * \alpha^S)$$

$$Y_t \in \{0,1\} \qquad \forall\, t \in T$$

$$\sum_{i\in I} p_i^S = 1$$

$$\sum_{j\in J} p_j^D = 1$$

Sample Parameter Values for Model

Parameter	Symbol	Value
Time periods between production and demand realization	ΔD	1
Time periods between supply realization and production	ΔS	1
Demand expected per time period for the entire time series	D	100
The incremental cost of procurement of per unit of raw material	C_1	20
The incremental cost of production of per unit of finished goods	C_2	5
The incremental cost of selling per unit of finished goods to fulfill the demand	C_3	1
Salvage value per unit of excess raw material	G_1	-1
Salvage value per unit of excess finished goods	G_2	-2
Selling price realized for any unit sold	P	35
Shortage cost of unfulfilled demand per unit	B	50
The incremental surge in demand (+ve) during the relevant time period	α^D	20%
The decremental wane in supply (-ve) during the relevant time period	α^S	-10%
CV for demand (assumed normal distribution)	CV_D	0.1
CV for supply (assumed normal distribution)	CV_S	0.05

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