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CHEMONICS





# Flowcasting the Vaccine Supply Chain

Charan Malemarpuram, Neeraj Thakare  
**Logistimo**



# Logistimo

Open source software and hosted services for supply chain & logistics in rural emerging markets

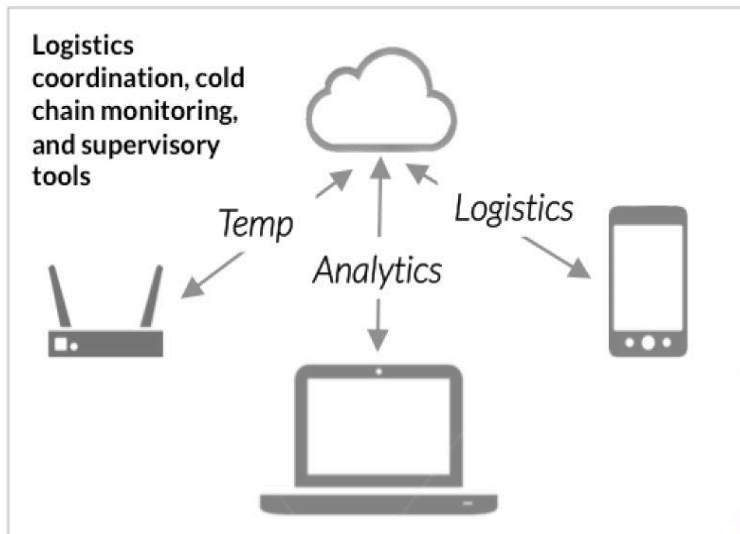
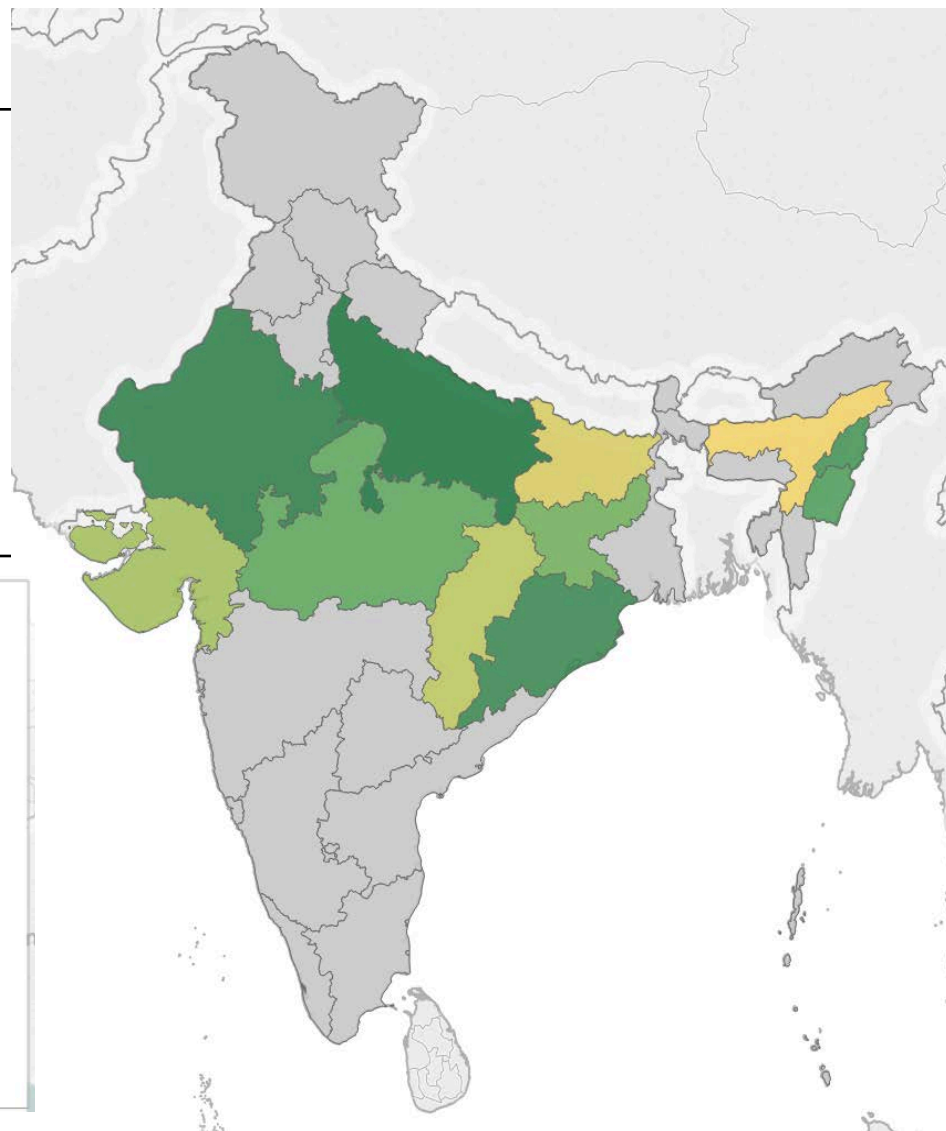




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# Immunization Supply Chain - India

States	11
Districts	358
Cold Chain Points	> 11,000
Population (cumulative)	661 mill
Birth Cohort (cumulative)	17 mill





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# Immunization Supply Chain - India

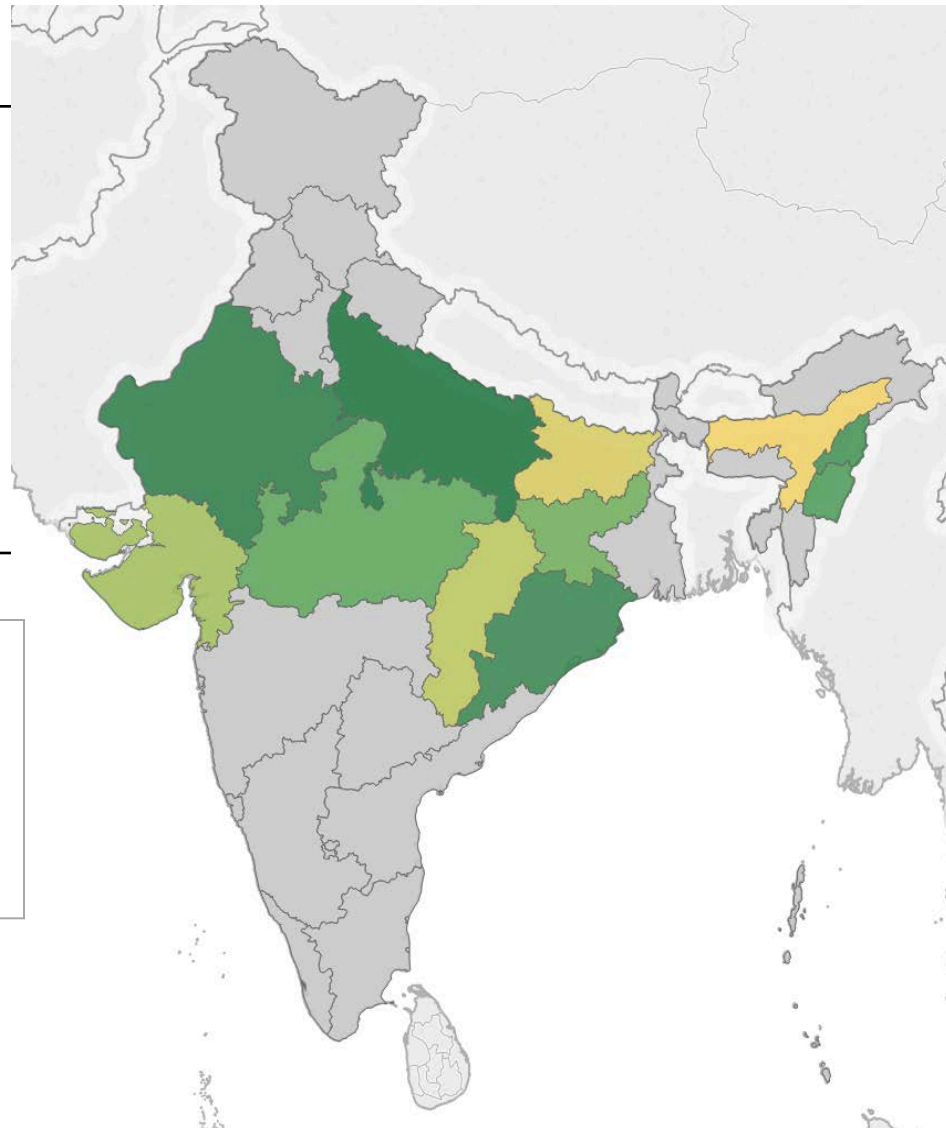
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States	11
Districts	358
Cold Chain Points	> 11,000
Population (cumulative)	661 mill
Birth Cohort (cumulative)	17 mill

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**> 99% availability**  
of all vaccines, with VVM 1 or 2 at the last  
CCP

**> 90% data reporting rate**  
within 48 hours of session days

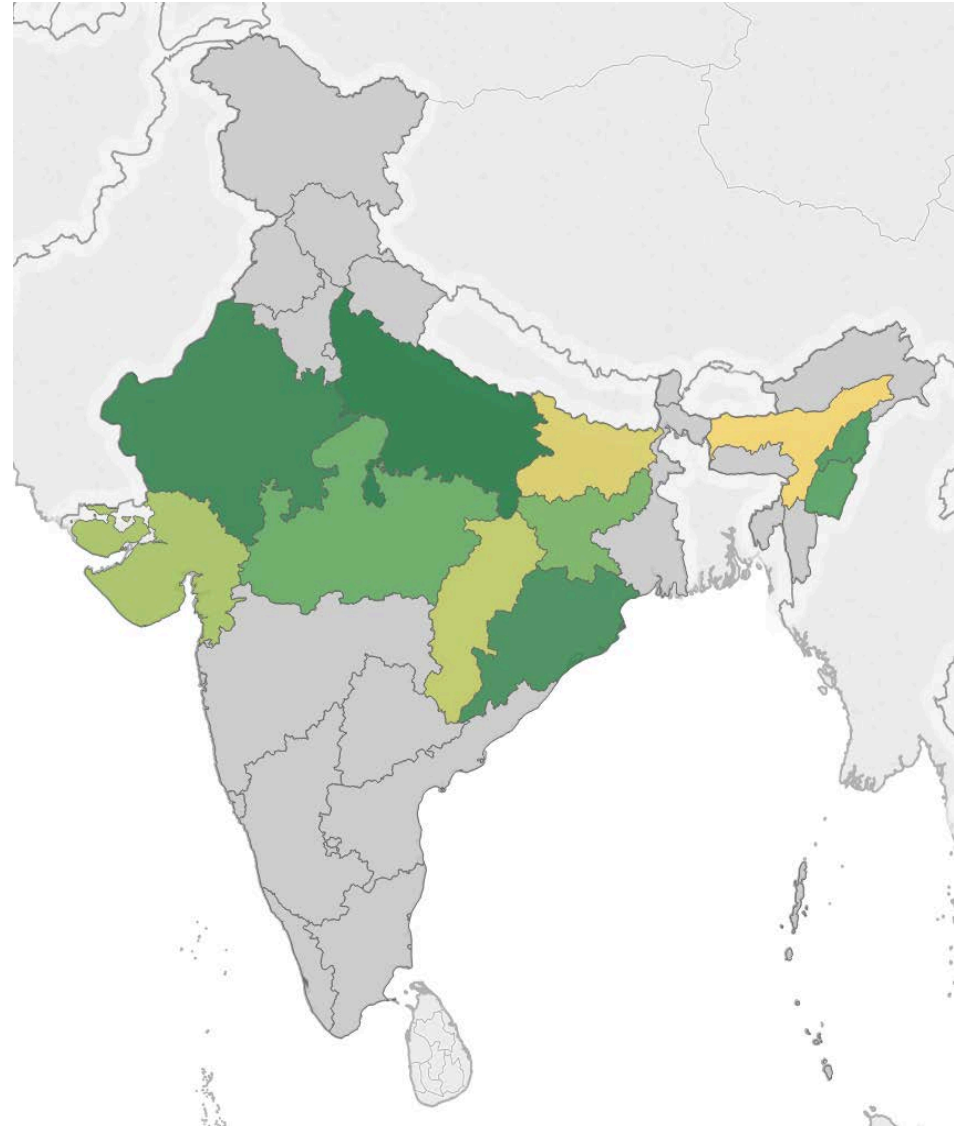




# Immunization Supply Chain - India

## Status Quo

- Population based heuristics determine replenishment (min, max)
- “static”, assumes deterministic demand
- One-size-fits-all at each level of the supply chain





## Status quo - example

Min/Max estimation for BCG vaccine in India :

***estimated monthly req.*** =  $(\text{annual birth cohort}/12) * 1 \text{ dose} * 2$  (wastage factor)

***buffer supply*** =  $0.25 * \text{monthly req.}$

***lead time consumption*** =  $0.25 * \text{monthly req.}$

***Min*** = *buffer* + *lead time* =  $0.5 * \text{monthly req.}$

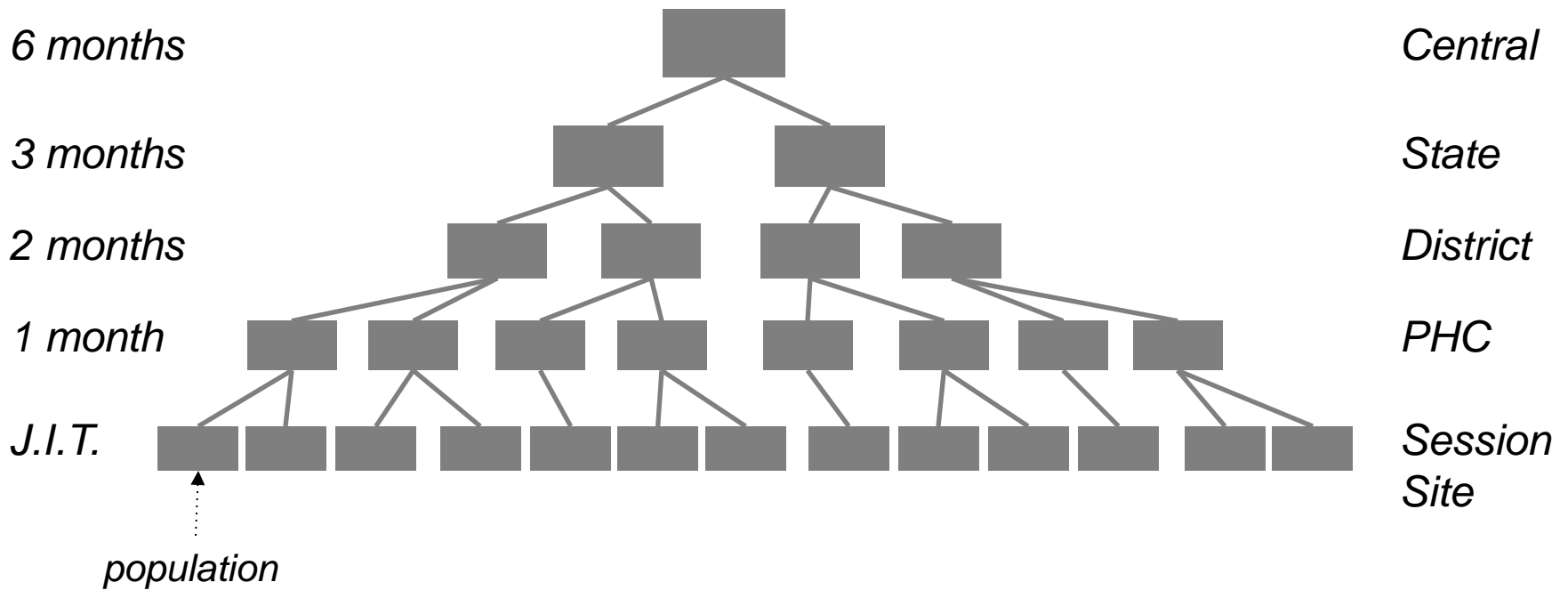
***Max*** =  $1.5 * \text{monthly req.}$



# Status quo

Periodic review & Heuristics

MIN/MAX





# Status quo

Periodic review & Heuristics  
MIN/MAX

## Challenges

- Inventory holding costs
- Wastage via expiry, temperature, etc.
- Cold chain capacity constraints
- Transportation



# Flowcasting

Last-mile  
forecasting



Real-time information  
symmetry



Optimization

---

## Hypothesis:

*Flowcasting* will better optimize replenishments by reducing –

- **Time spent by commodities in the pipeline**
- And therefore losses due to
  - Temperature excursions
  - Expiry
  - High cold-chain capacity



# Types of Inventory Control Policy

Fundamental purpose of a replenishment control system –

- How often to check inventory status?
- When to replenish?
- How much to replenish?



# Types of Inventory Control Policy

Policy Flavor	Type	Description
{s, Q}	Continuous review	Order-point, Order-quantity
{s, S}	Continuous review	Min/Max
{R, S}	Periodic review	Periodical top-up
{R, s, S}	Periodic review	Combination order-point periodic

s : order point  
 Q : order quantity  
 S : order up-to level  
 R : periodicity of review

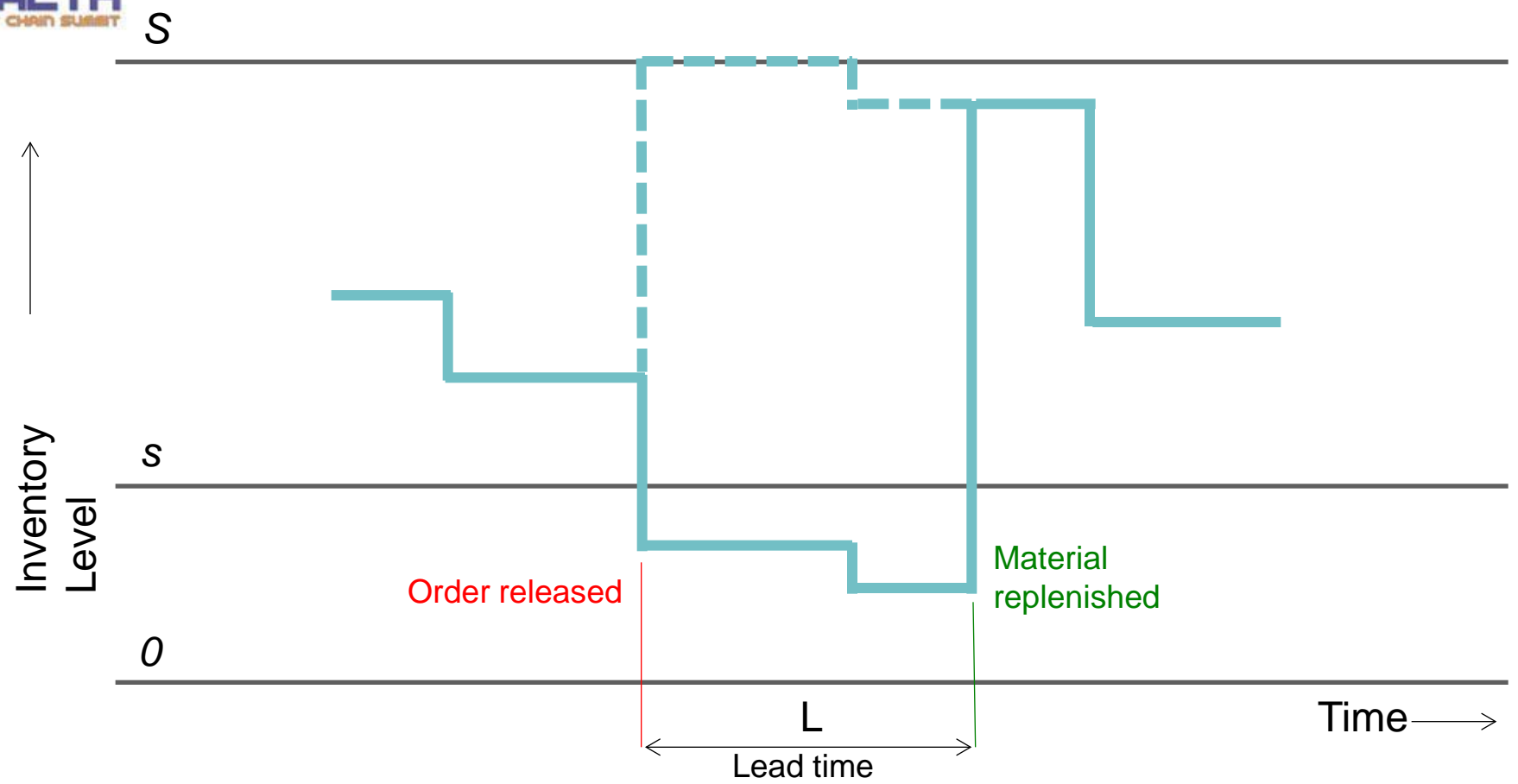




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# Flowcasting

Continuous review & optimization  
{s,S}



s : order point  
S : order up-to level

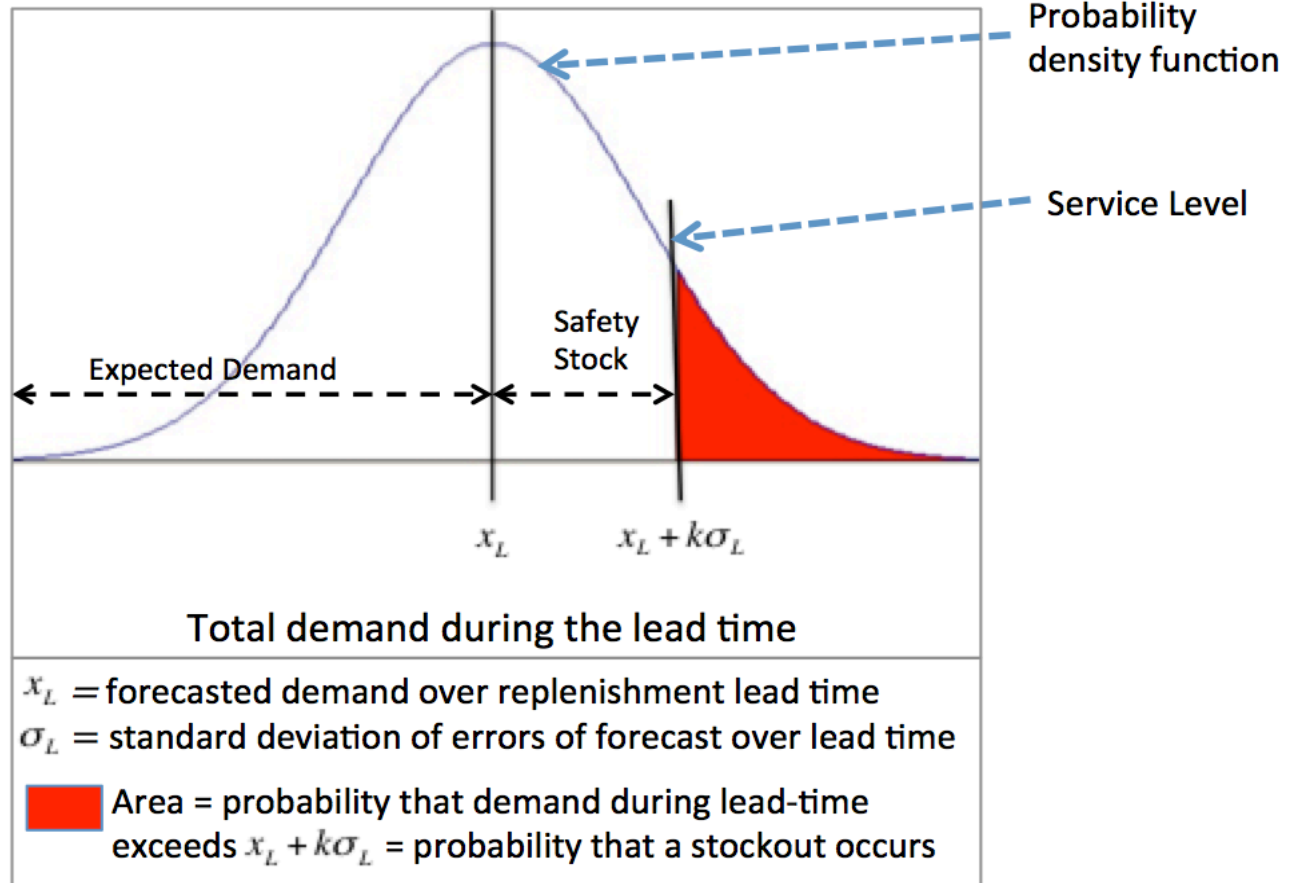


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# Flowcasting

Continuous review & optimization

{s,S}



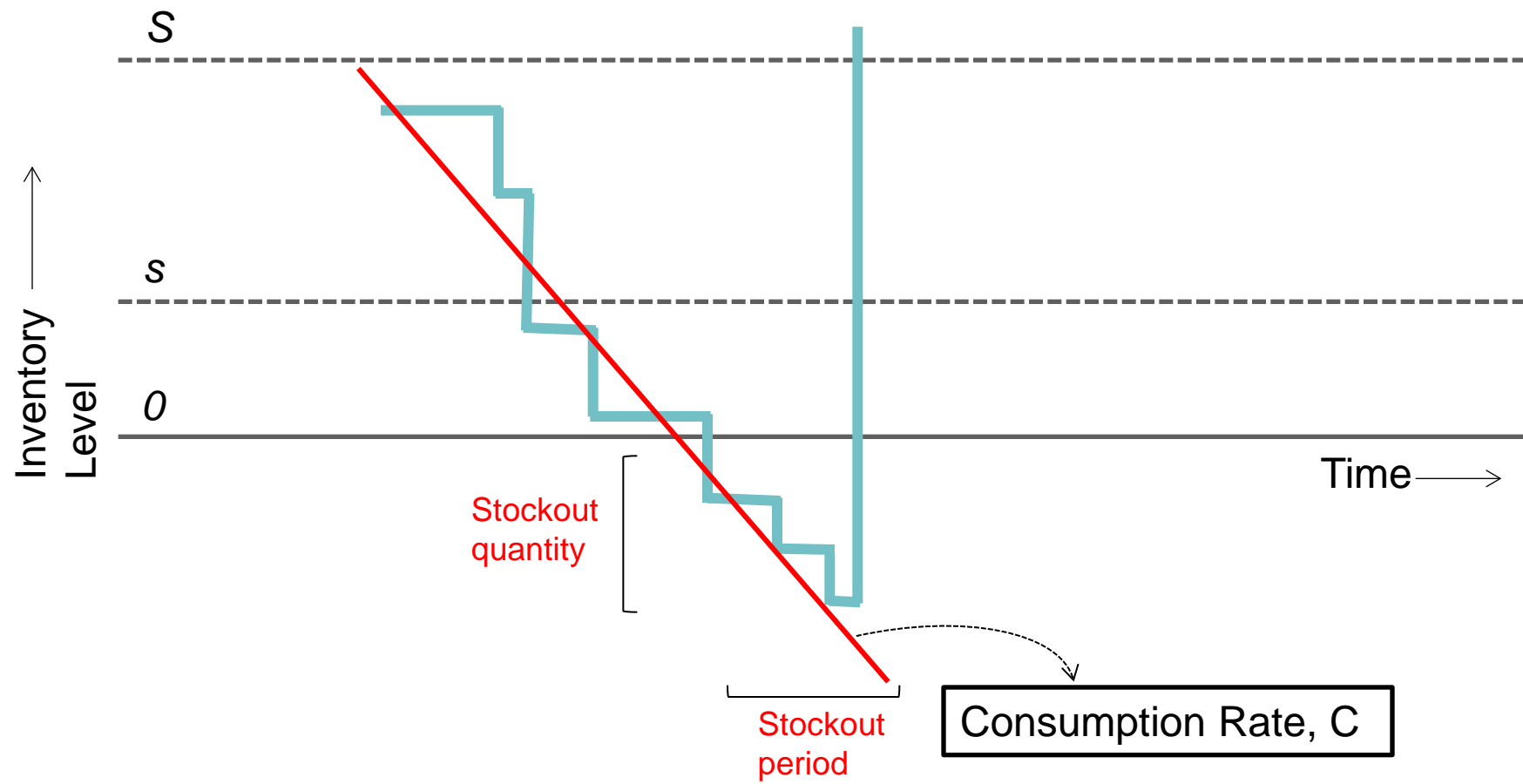
$$\text{Reorder point: } s = x_L + k\sigma_L$$



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# Flowcasting

Continuous review & optimization  
{s,S}



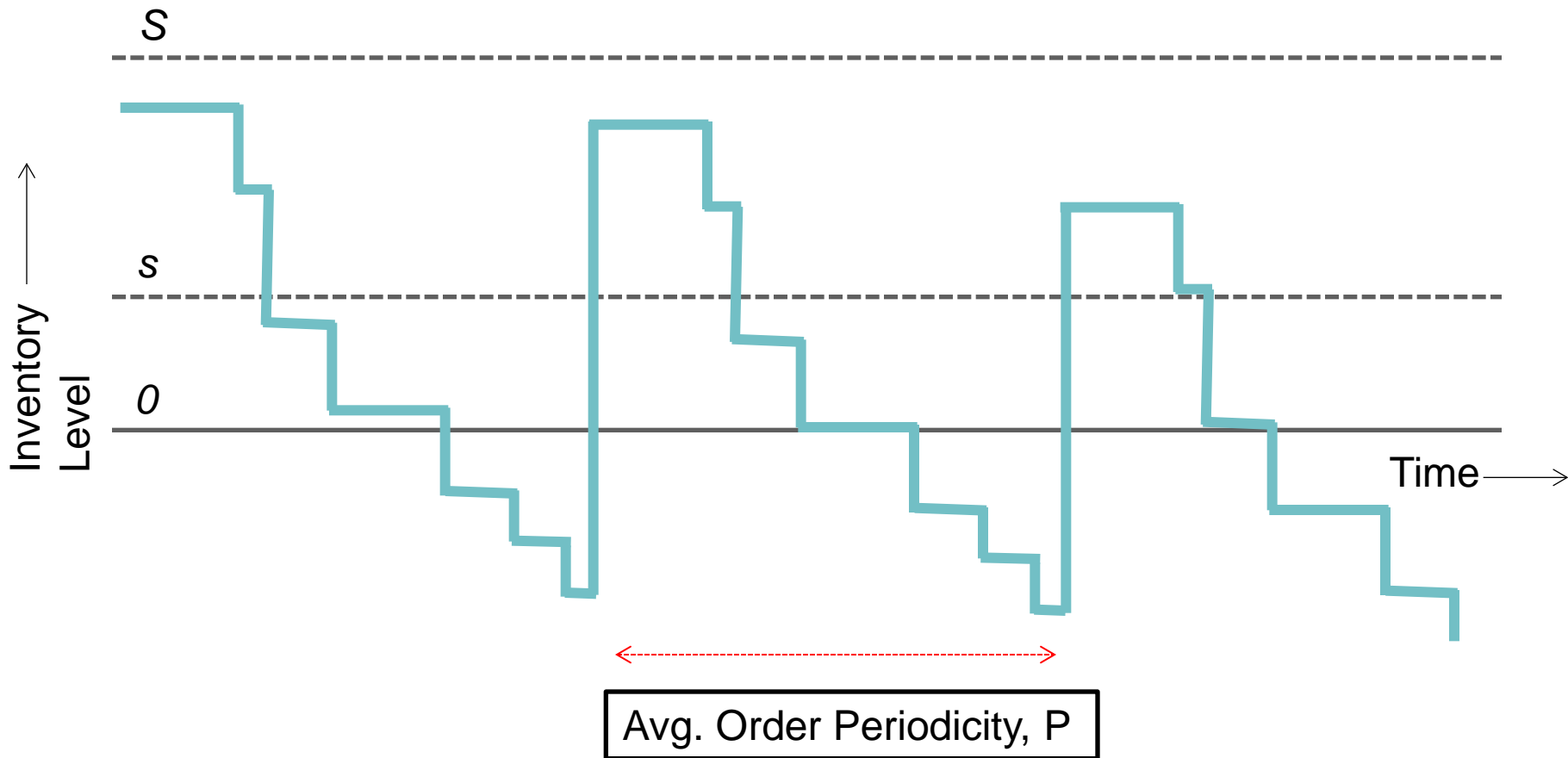


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# Flowcasting

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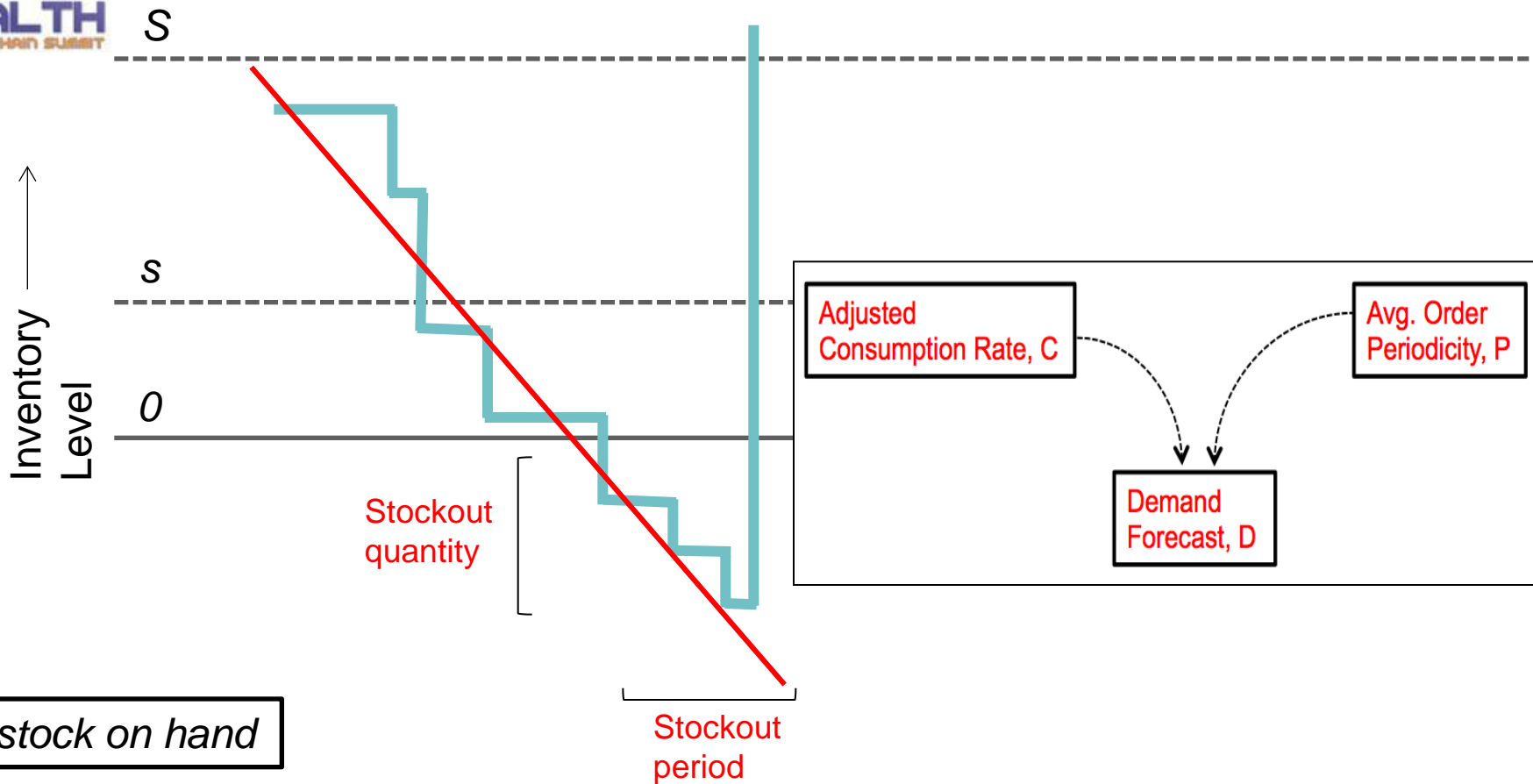


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# Flowcasting

Continuous review & optimization

{s,S}



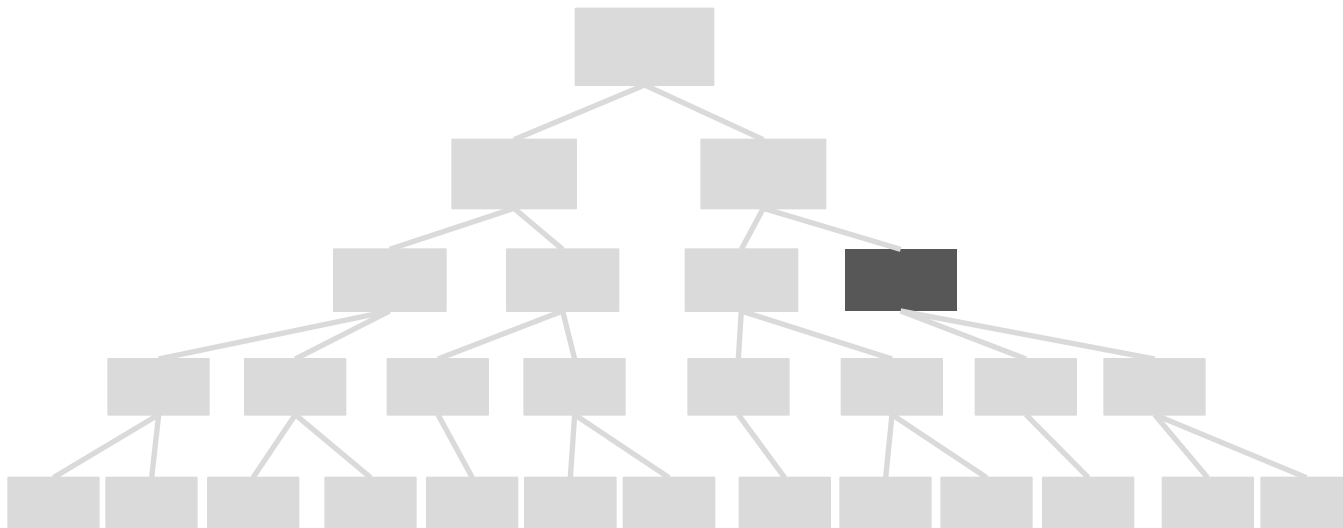
$I = \text{stock on hand}$

*Optimal replenishment quantity:  $Q = D + s - I$*



# Flowcasting

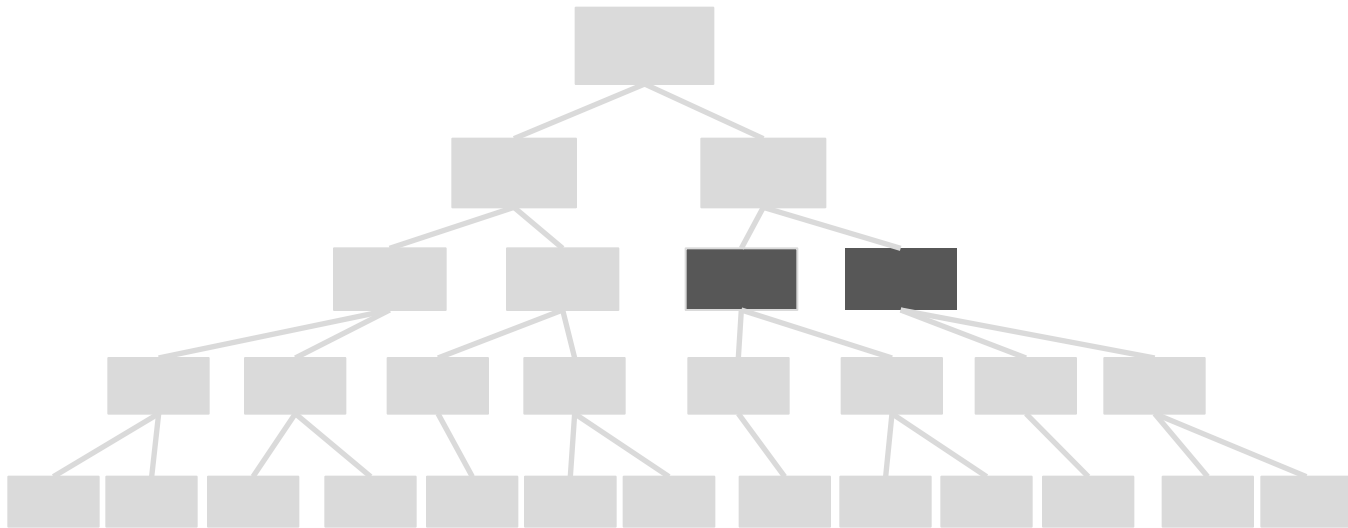
## Continuous review & optimization



- 
- *Historical lead times*
  - *Stock on hand*
  - *Adjusted consumption / forecasted demand*

# Flowcasting

## Continuous review & optimization

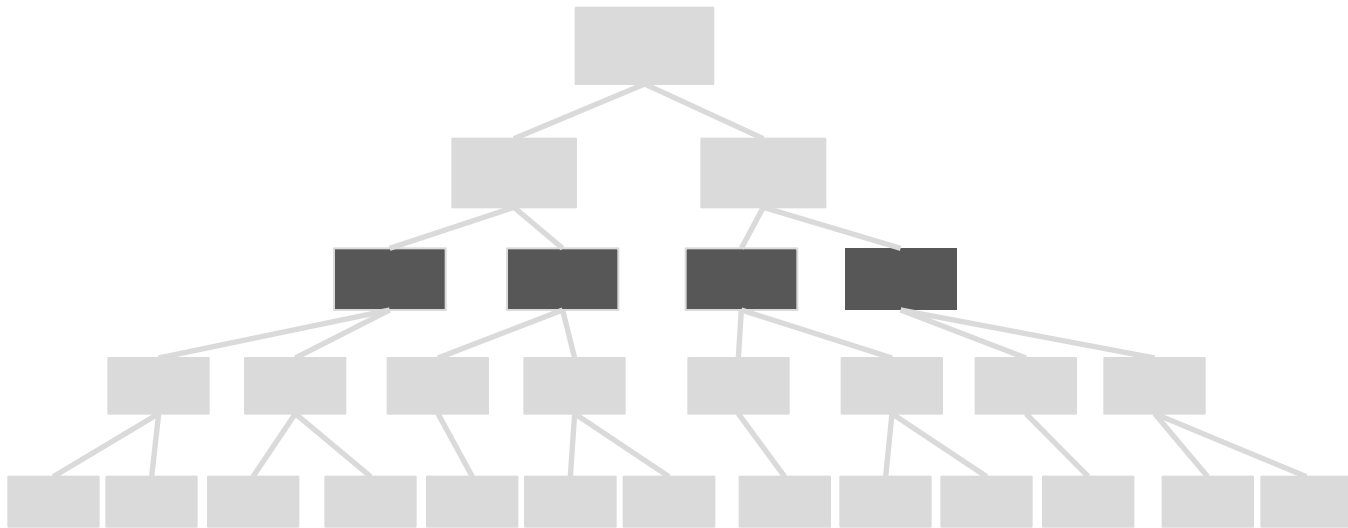


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# Flowcasting

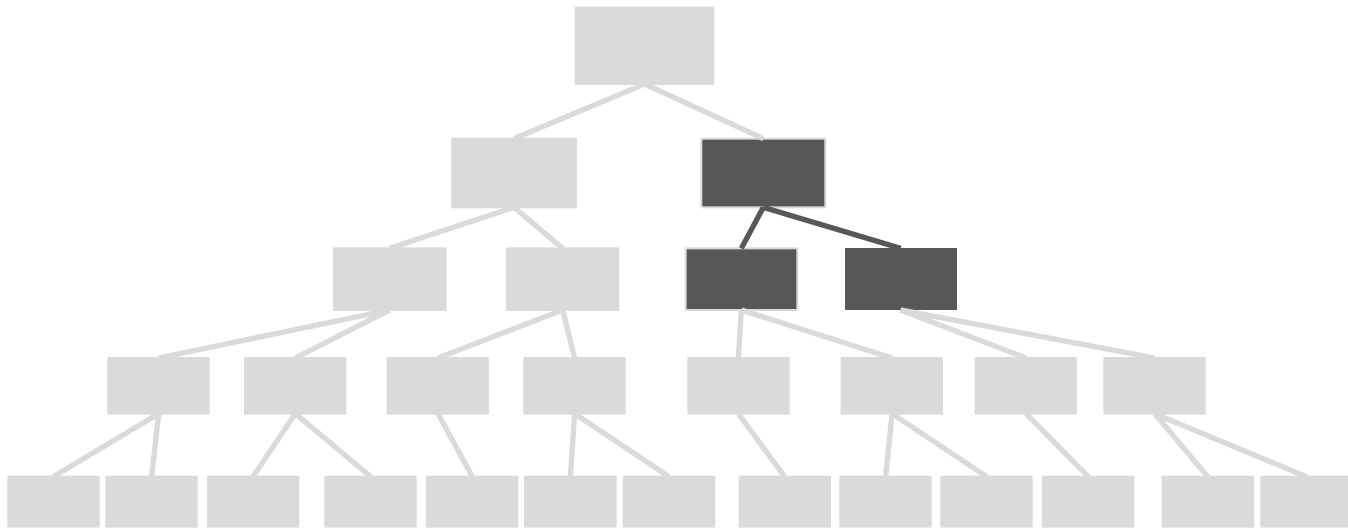
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# Flowcasting

Continuous review & optimization

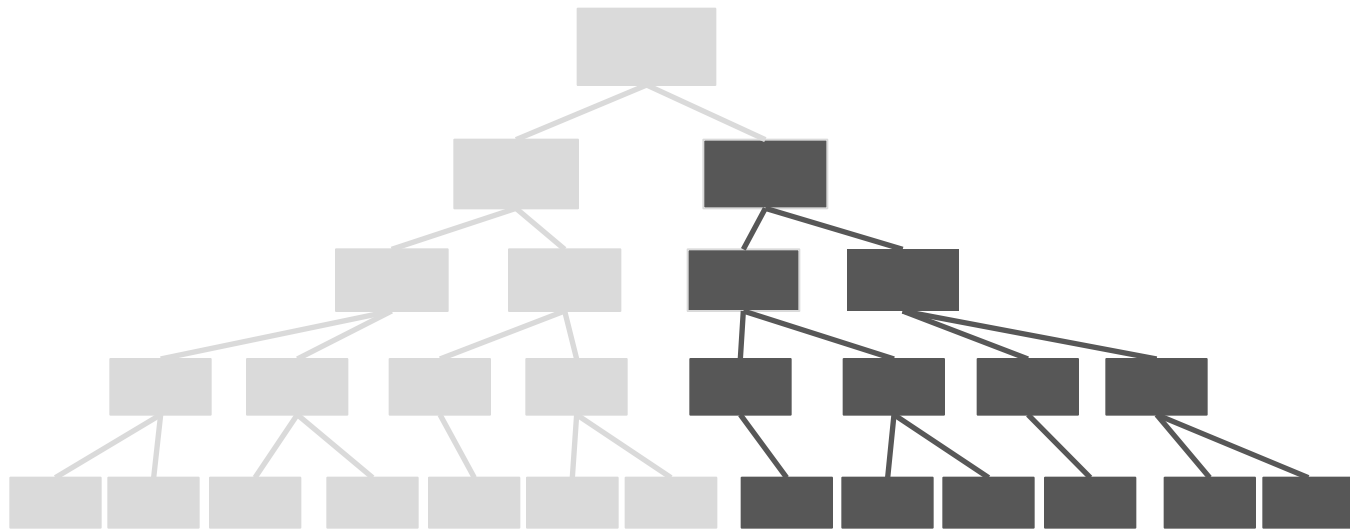


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# Flowcasting

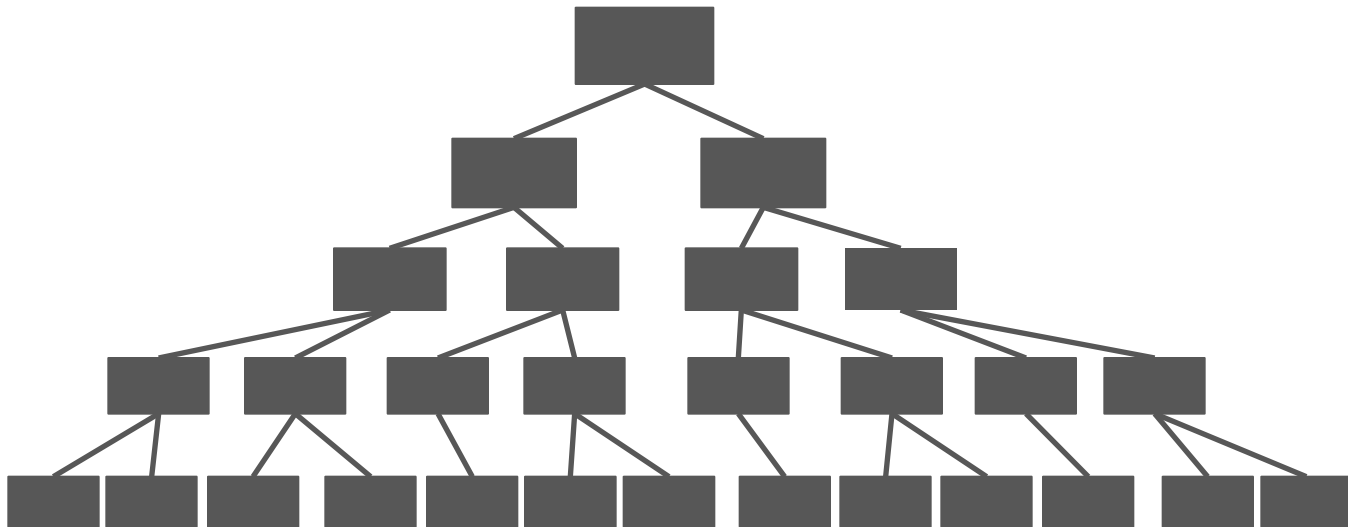
Continuous review & optimization



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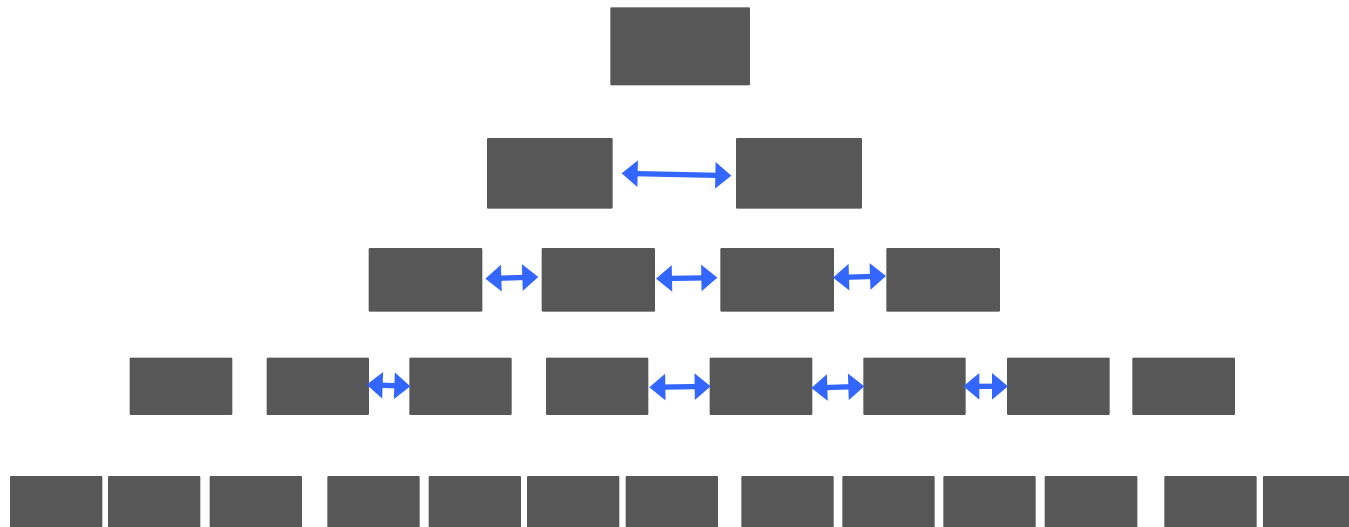
# Flowcasting

Continuous review & optimization



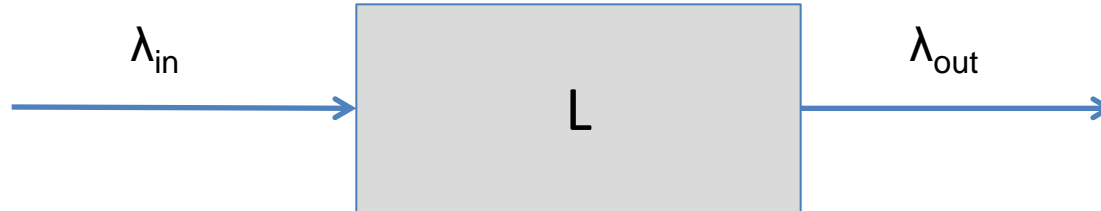
- 
- *Historical lead times*
  - *Stock on hand*
  - *Adjusted consumption / forecasted demand*

# Opportunistic Stock Rebalancing



- Adjust initial stock levels as per real demand patterns
- Replenishment policies would eventually adjust to actual consumption levels and rebalancing would be atypical

# Little's Law



$$L = \lambda w$$

*avg. stock on hand = flow rate (replenishment rate) \* avg. inventory holding time*

## *Assumptions:*

- Flow conservation, i.e. avg.  $\lambda_{in} = \text{avg. } \lambda_{out}$*
- System is 'stable', i.e. total inventory in the system is roughly constant*



# Pilot Design

- *Flowcasting* to be piloted in 3 states with 160 districts and 4568 facilities having stable deployments and high data quality
- Subset of districts to be chosen as treatment group based on
  - High reporting rates (> 95%)
  - Inventory flows in relative equilibrium (as per *Little's Law*)
- Measuring impact (before and after) –
  - Availability % (service levels)
  - Inventory holding times (using *Little's Law*)



# Technology



# Implementation considerations

- Forecasting Accuracy
- Flexibility
- Usability
- Scalability



# Forecasting Accuracy

- Data quality
  - Forecasting is only as good as the data available for computation.
- Computation model
  - Choose the right computational model with due consideration for demand supply pattern.
- Real time feedback. Re compute when
  - Inventory hits safety stock.
  - Upstream ships or confirms an Order.
- Enable forecast vs actual comparison to build trust.



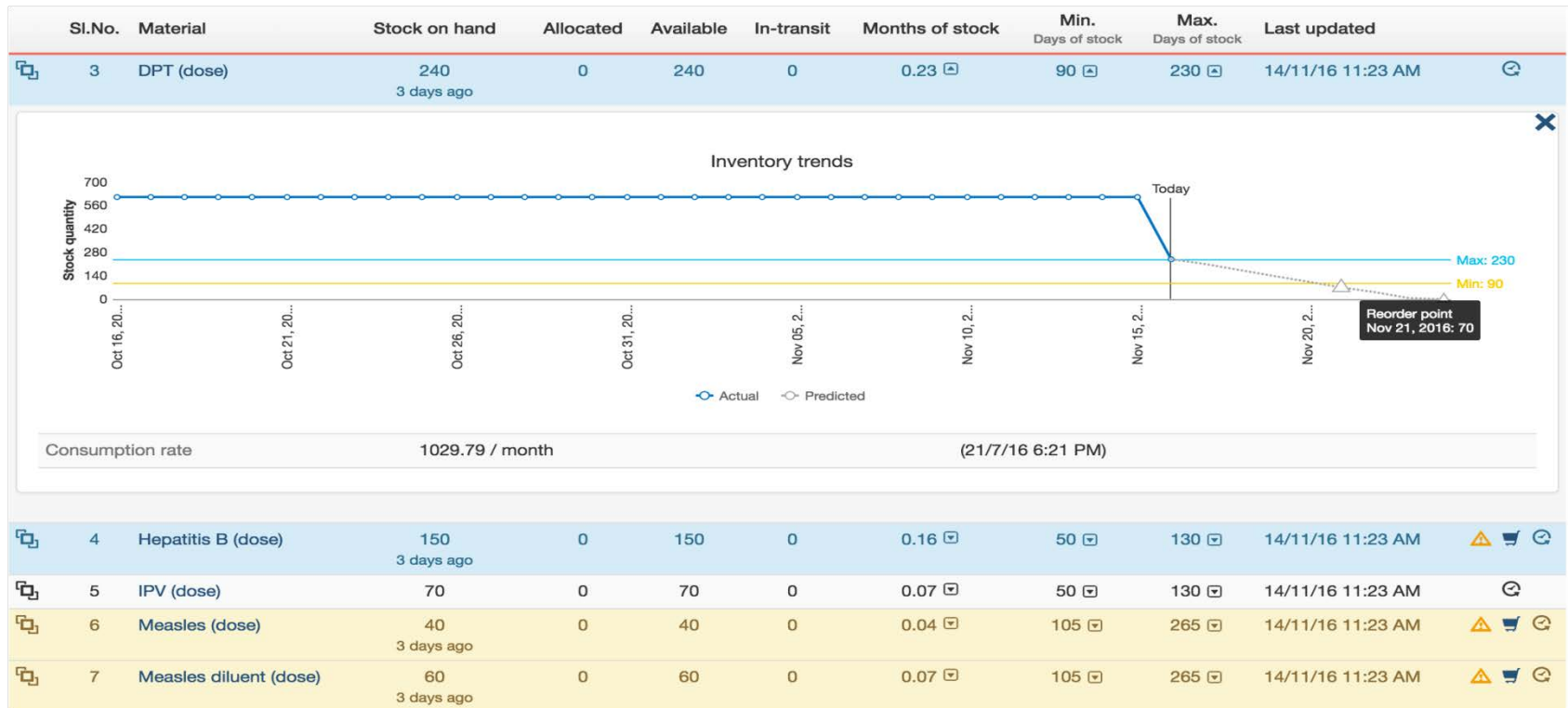
# Flexibility

- One solution does not fit all.
- Each Store ( Hospital, National warehouse) is unique.
- Each SKU ( Material ) at a store is unique.
- Allowing ability to customize is important
  - Inventory policies
  - Order periodicity
  - Computation models



# Usability

- Simple and intuitive





# Usability

- Allow users to override recommendations
  - System cannot capture all extrinsic factors
  - Emergency situations like floods, unrest, earth quakes and so on.



# Scalability

- System should be able to project forecast or rebalancing for
  - 1 store or 100,000 stores.
  - 1 SKU or 1000 SKU's.
  - Daily reporting / monthly reporting / Real time (POS).
- One of our major deployments has about
  - **One Million** inventory items ( SKU @ Store ).
  - **250 Million inventory updates** to be analyzed every day.



# Thank you!

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