Logistics Cost Minimization and Inventory Management Decision for Yarn Manufacturers in China

Capstone Project Presentation

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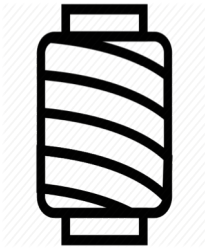

Overview: Facts about Cotton

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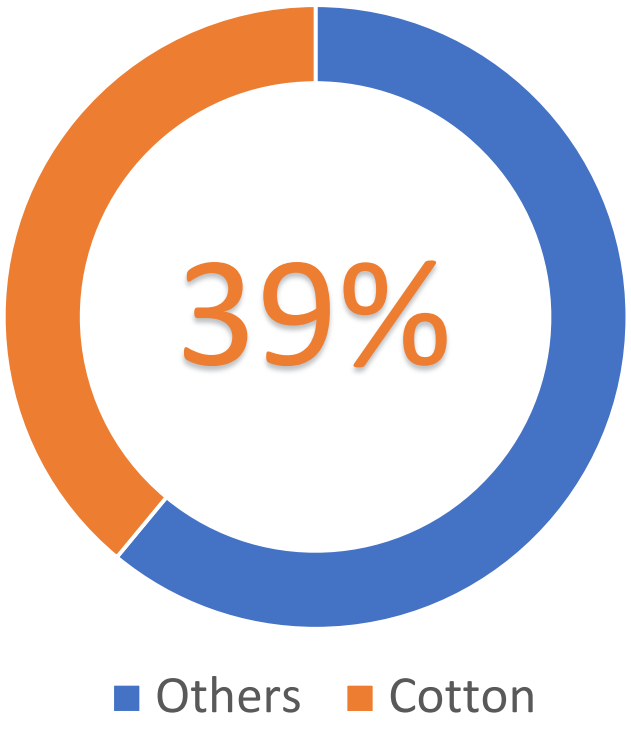
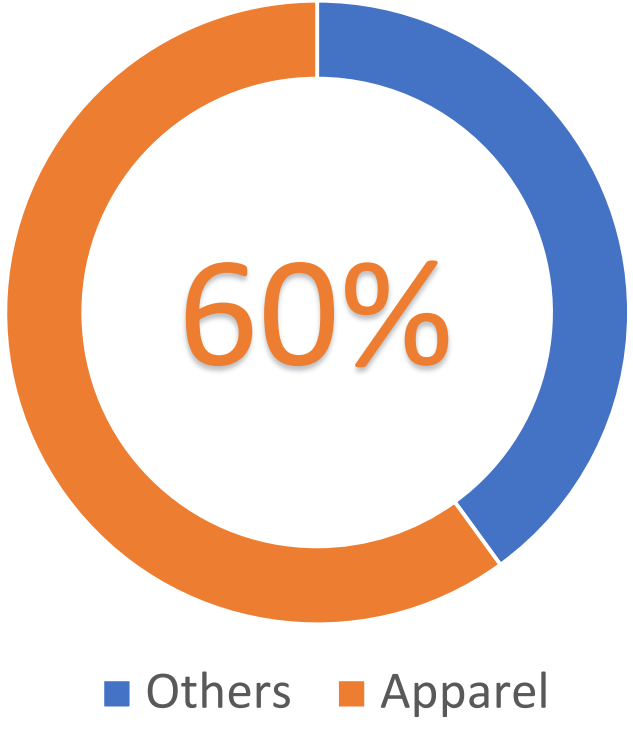
Fiber Market

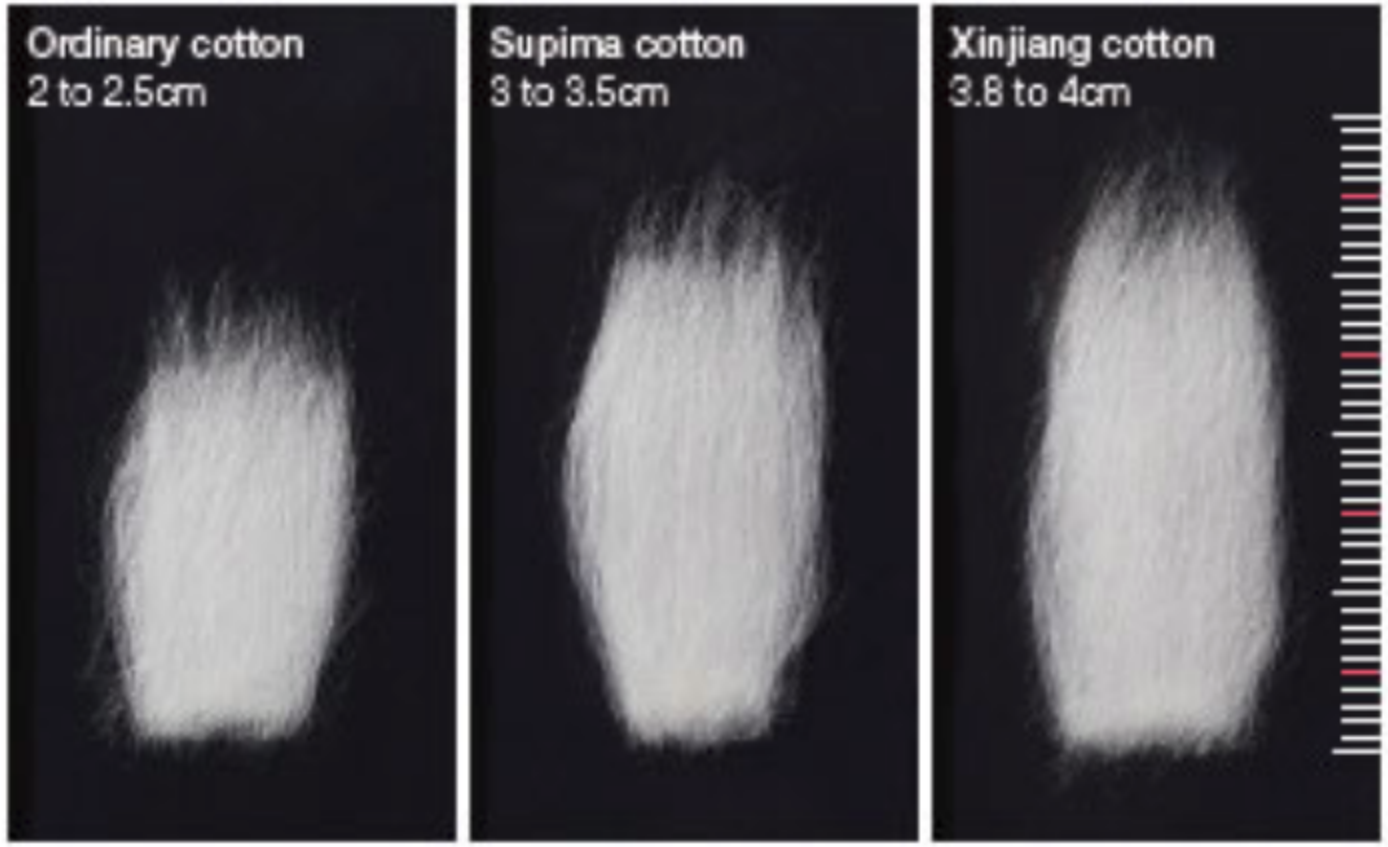


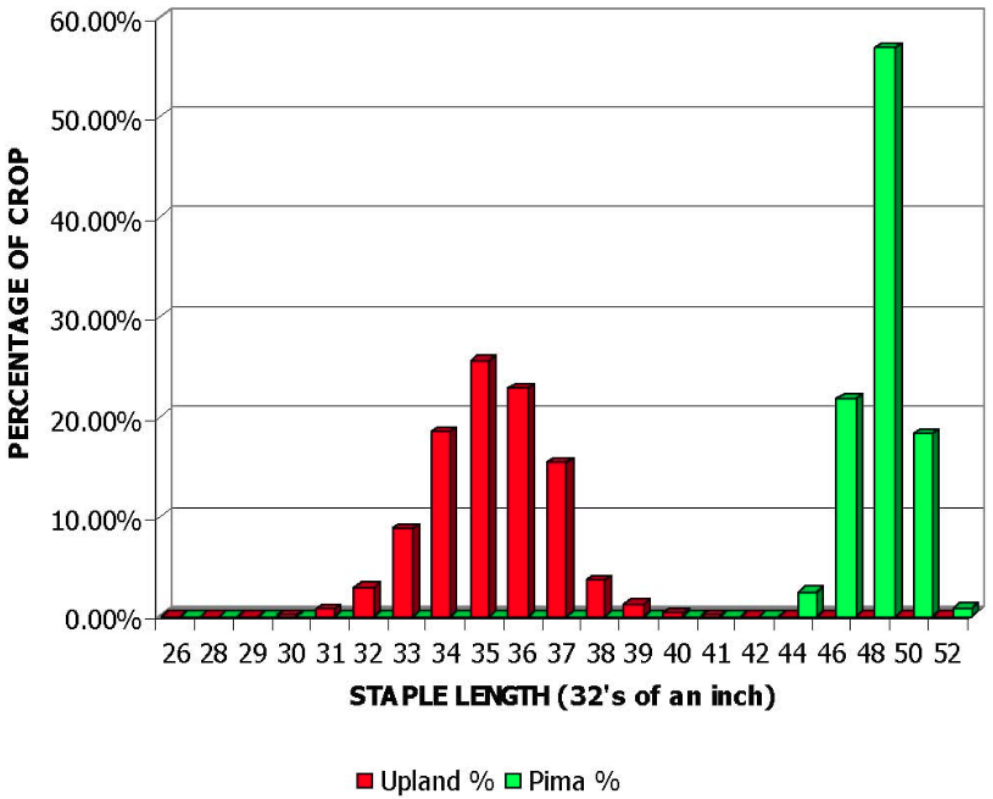
Finished Goods



USD 21B of Cotton in Apparel

Overview: Cotton Properties





Overview: Seasonality of Cotton

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Harvest

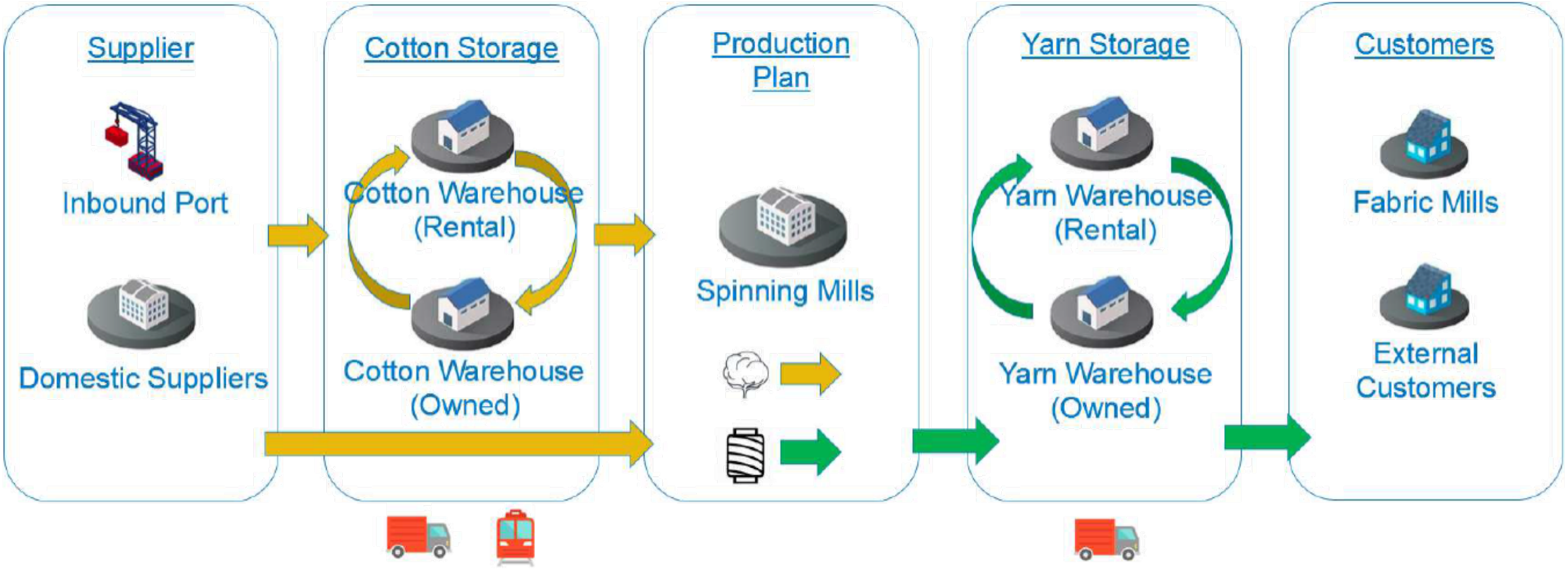
Ginning

Cotton Bale

Suppliers

China	US	India	Egypt	AUS
Oct	Oct	Oct	Oct	May
Mar	Mar	Mar	Mar	Oct

Overview: Yarn Manufacturing



Motivation: High Growth in Logistics Cost

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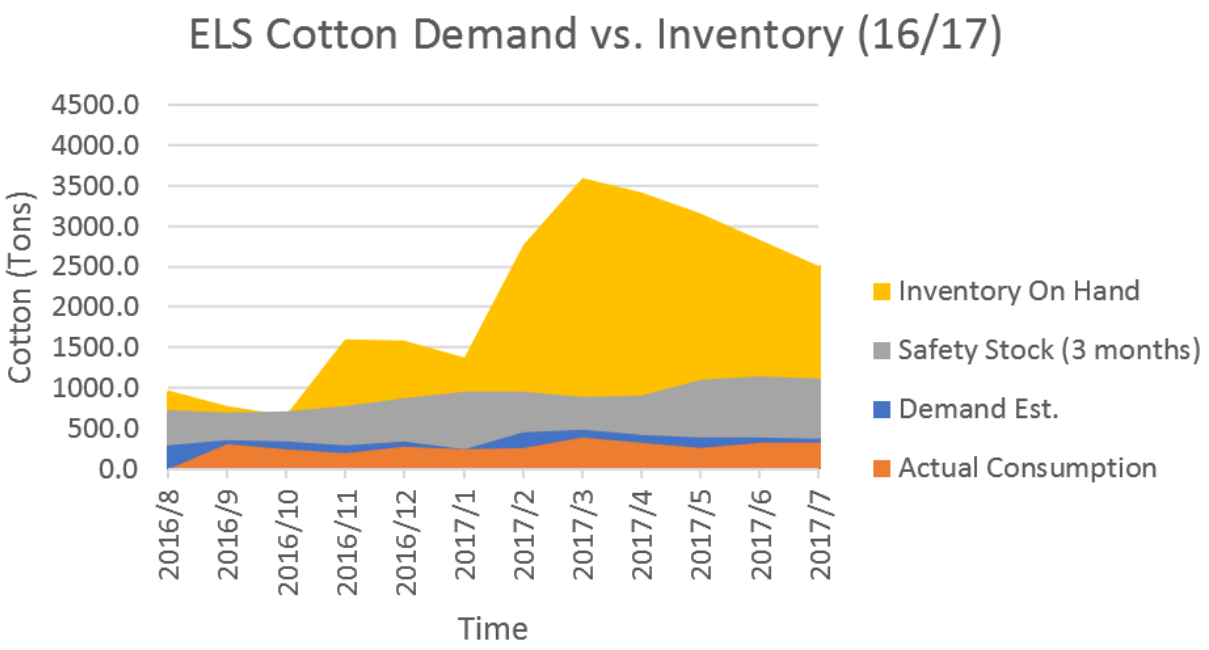
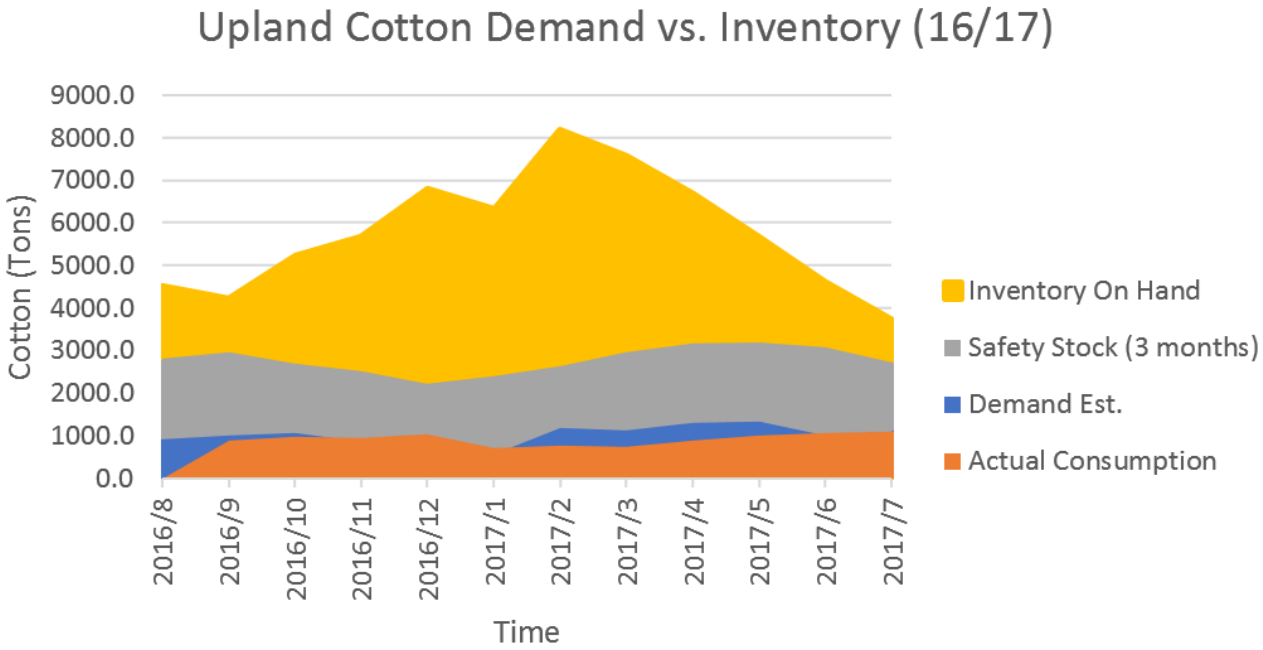
- IDC (2014): **7.8%** of Sales in Manufacturing Business are Logistics Cost
- Wang L. (2014): 2001 - 2011
  - Transportation Cost : 1.1 to **4.4 trillions** in RMB (USD 170B to 688 B)
  - Storage Cost : 0.6 to **2.9 trillions** in RMB (USD 93.8 B to 453.7 B)
- Warehouse rental cost : +3%
  (Beijing, Shanghai, Ningbo, Guangzhou, Nanjiang)
- Company experienced on rental cost increase season 17/18: **+ 8%** (Guangzhou)
  - i.e. **RMB 7.02MM + 0.56 MM** (~USD 1.19MM)

Observations: High Level of Inventory





Industrial / Corporate Drivers

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Industry

- Cotton spot price spike around 2011 (Cotton Outlook, 2017)

- Cotton price pressure : synthetic materials
- Fast fashion : 30-45 days > 8-20 days
- National import quota and grace period

Company

- Two new spinning mills in 2018/19 at Guilin
- Shifting demand from woven to knit products
- Unstable demand in organic cottons
- Criticality of cotton in corporate culture

Current Replenishment Decision

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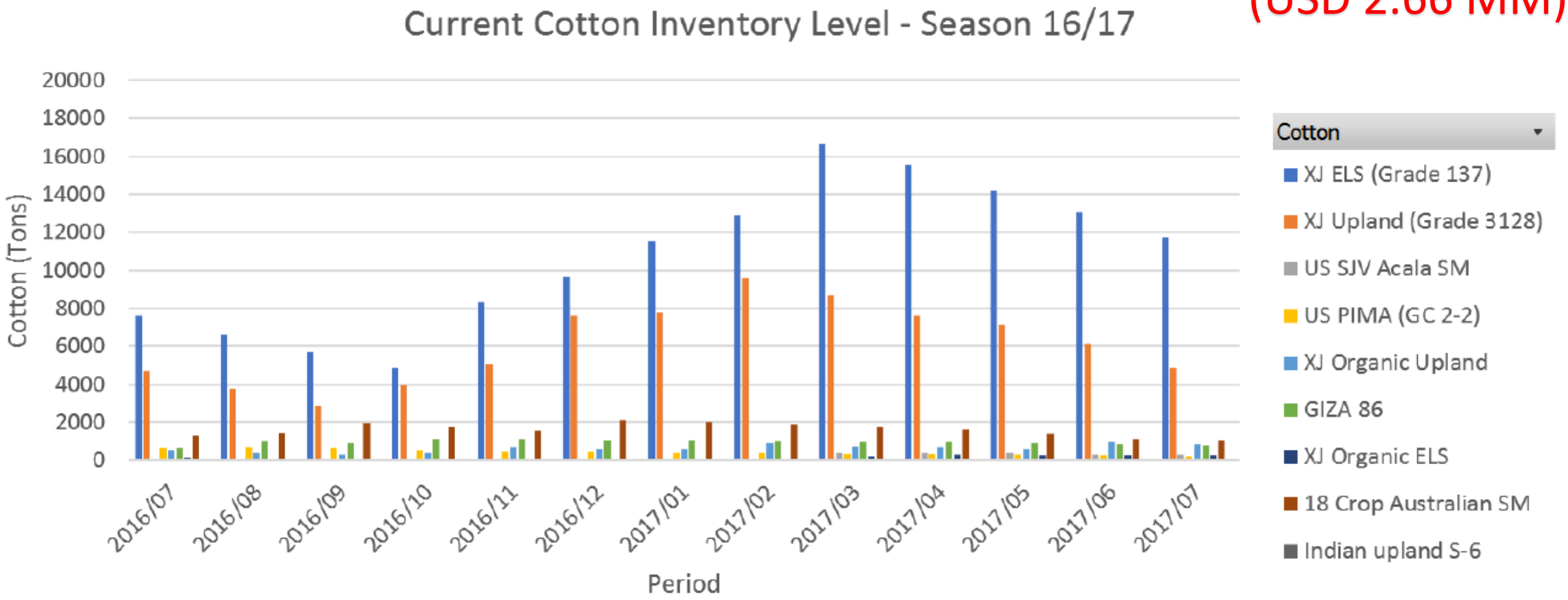
Total Logistics Cost: RMB 16.9 MM (USD 2.66 MM)



Questions

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How can the Yarn Manufacturers make better replenishment decisions and inventory management decisions to minimize the total logistics cost of the supply chain without impacting the production stability?

Gap: Academic and Yarn Industry

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- Quantitative tools to guide the yarn manufacturers in making inventory replenishment decisions with minimum logistics cost

  Consider:

  (i) Seasonality of Cotton
  (ii) Volatile cotton prices and supplies in spot markets
  (iii) Warehouses regions and costing structures
  (iv) Production and Storage capacities
  (v) Government Policies to Cotton Spinning industry
  (vi) Cotton Mixing to bridge the yarn demand with cotton supply
  (vii) Safety stock policy for production stability

Optimization Problem (MILP)

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High Stock Level

- Transportation cost (Train vs. Truck)
- Ordering cost (Smaller vs. Larger orders)
- Spot Market Prices of Cotton

- Storage cost in cotton & yarn (Fix / Variable)
- Opportunity cost of owned warehouses
- Working capital cost

Low Stock Level

Constraints

- Transportation Route & Product-Specific Model Selection
- Availability/Seasonality of Cotton Types
- Government Import Quota for Yarn Manufacturers
- Demand of yarn products
- Cotton Mixing
- Safety stock policy
- Spinning and Storage capacity

python

Project Methodology

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1. Business Process Mapping

a) Cotton consumption forecast (Spinning Mill, Sales)
b) Cotton procurement (Sourcing)
c) Cotton transportation and storage (Logistics)
d) Order processing (Sales)
e) Technical design and production planning (Spinning Mill)
f) Yarn transportation and delivery (Logistics)

2. Data Collection and Pre-Processing

a) Obtain costing drivers and the unit rates
b) Collect historical statistics including inventory level, expenses and product demand
c) Gather information of production and storage capacities
d) Clean abnormal data and discard outliners

3. Build Optimization Model

a) Re-construct the material and goods logistic networks
b) Define MILP model
c) Implement MILP in Python
d) Grouping product collections and cotton mixing recipes
e) Format gathered data into csv format for execution
f) Run optimization of case studies

4. Sensitivity Analysis

a) Change spot price in ELS
b) Change spot price in Upland

Case Studies

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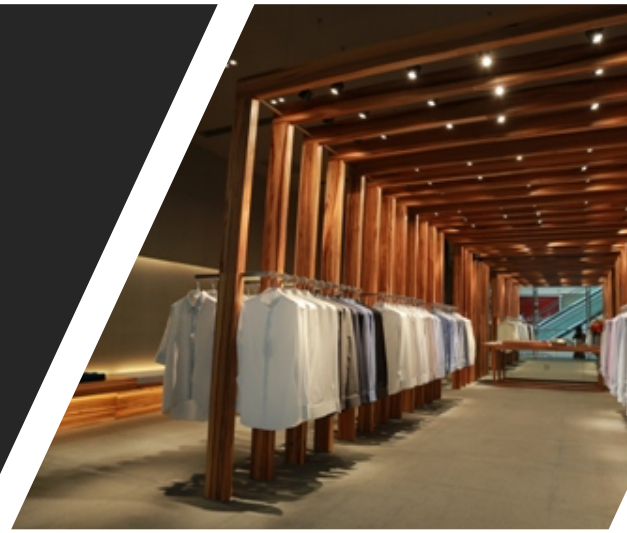
- Hong Kong based Shirt-Making Company
- 100 million shirts per year
- Vertical supply chain: Cotton to Retail
- Customers : Hugo Boss, Tommy Hilfiger, Ralph Lauren, Muji, Brooks Brothers, Apple, Nike, …
- 5+2 Spinning Mills: Xinjiang(3), Guilin(1+2), Foshan(1)
- Annual Budget on Cotton (2016): USD 74.9M
- Average inventory level (2016): 49.8k tons cotton



MILP: Minimize Material Prices and Logistics Cost as Objective Function

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$$\text{Min } Z = \sum_{\substack{c\in C, s\in S, g\in G \\ t\in T}} \Big(\sum_{a\in A, l\in L} xc\_sw_{tgcsla} + \sum_{\substack{r\in R, m\in M, \\ l\in L}} xp\_sm_{tgrcslm} \Big) \times p_{cst} + \sum_{c\in C, s\in S} \sum_{t\in T} OF_{tcs} \times oc_{cs}$$

- Price of Cotton
- Ordering Cost

$$+ \sum_{a\in A} \sum_{t\in T, c\in C} IC_{atc} \times hc_a + \sum_{b\in B} \sum_{t\in T, y\in Y} IY_{bty} \times hy_b + \sum_{a\in A} OA_a \times hcf_a + \sum_{b\in B} OB_b \times hyf_b$$

$$+ \sum_{a\in A} \sum_{t\in T, c\in C} IC_{atc} \times oppc_a + \sum_{b\in B} \sum_{t\in T, y\in Y} IY_{bty} \times oppy_b$$

- Storage Cost – Variable
- Storage Cost – Fix
- Opportunity Cost – Owned Warehouse

$$+ \sum_{\substack{a\in A, m\in M, \\ g\in G, t\in T}} \sum_{\substack{c\in C, r\in R, \\ }} xp\_wm_{tgrcam} \times tc\_wm_{tagm} + \sum_{\substack{a\in A, l\in L, \\ g\in G, t\in T}} \sum_{c\in C, s\in S} xc\_sw_{tgcsla} \times tc\_sw_{tlga}$$

$$+ \sum_{\substack{l\in L, m\in M, \\ g\in G, t\in T}} \sum_{\substack{r\in R, c\in C, \\ s\in S}} xp\_sm_{tgrcslm} \times tc\_sm_{tlgm} + \sum_{\substack{a, a1\in A, \\ g\in G, t\in T}} \sum_{c\in C} xc\_ww_{tgcaa1} \times tc\_ww_{taga1}$$

- Cotton Transportation Cost

$$+ \sum_{\substack{m\in M, b\in B, \\ g\in G, t\in T}} \sum_{y\in Y} xe\_mw_{tgymb} \times ty\_mw_{tmgb} + \sum_{\substack{m\in M, f\in F, \\ g\in G, t\in T}} \sum_{y\in Y} xe\_mf_{tgymf} \times ty\_mf_{tmgf}$$

$$+ \sum_{\substack{b\in B, f\in F, \\ g\in G, t\in T}} \sum_{y\in Y} xe\_wf_{tgybf} \times ty\_wf_{tbgf}$$

- Yarn Transportation Cost

MILP: Definitions of Modeling Entities

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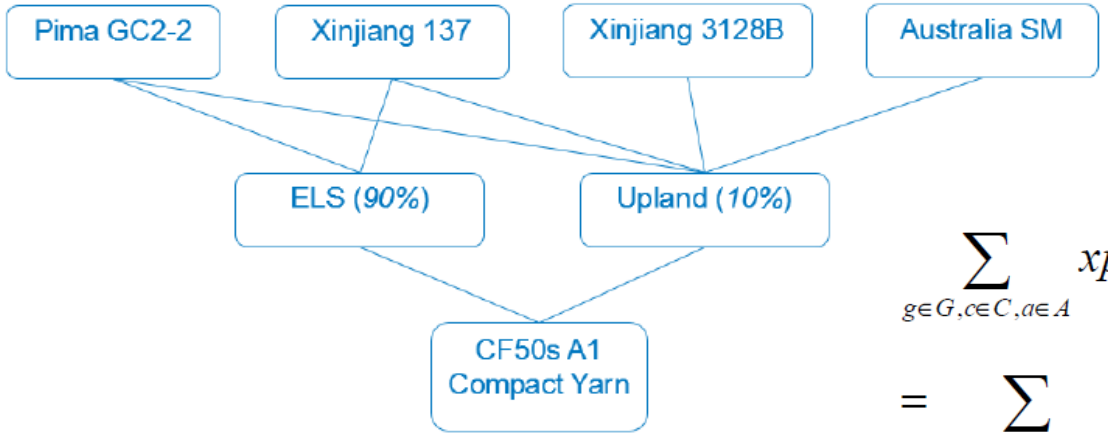
Definitions

c = cotton types
y = yarn types
s = cotton suppliers
l = inbound ports
m = spinning mills
a = cotton warehouses
b = yarn warehouses
f = fabric mills
g = mode of transportations
t = time period
r = cotton properties required
p = price of cotton
oc = ordering cost of cotton
hc/hy = holding cost of cotton/yarn in warehouse
hcf/hyf = fix cost of cotton/yarn warehouse
xc_XX = amount of cotton transport between warehouses and suppliers
xp_XX = amount of cotton input to spinning mills for production
tc_XX = the transportation cost of the transfer
IC/IY = storage cost of cotton/yarn

oppc/oppy = opportunity cost of occupying the owned cotton/yarn warehouse
OF = linking variable of cotton purchase
OA/OB = linking variables flags warehouses in service

MILP: Material Composition of Cotton Yarn



$$\sum_{g\in G,c\in C,a\in A} xp\_wm_{tgrcam} + \sum_{\substack{g\in G,c\in C,\\ s\in S,l\in L}} xp\_sm_{tgrcslm}$$

$$= \sum_{g\in G,f\in F,y\in Y} (xe\_mf_{tgymf} \times cd_{tmyr} \times u_y) + \sum_{g\in G,b\in B,y\in Y} (xe\_mw_{tgymb} \times cd_{tmyr} \times u_y)$$

$$\forall m\in M, r\in R, t\in T \quad (8)$$

$$\sum_{\substack{g\in G,s\in S,\\ l\in L}} xp\_sm_{tgrcslm} + \sum_{g\in G,a\in A} xp\_wm_{tgrcam} \le cca_{tmcr} \times BigNum$$

$$\forall c\in C, r\in R, m\in M, t\in T \quad (9)$$

Optimization Results

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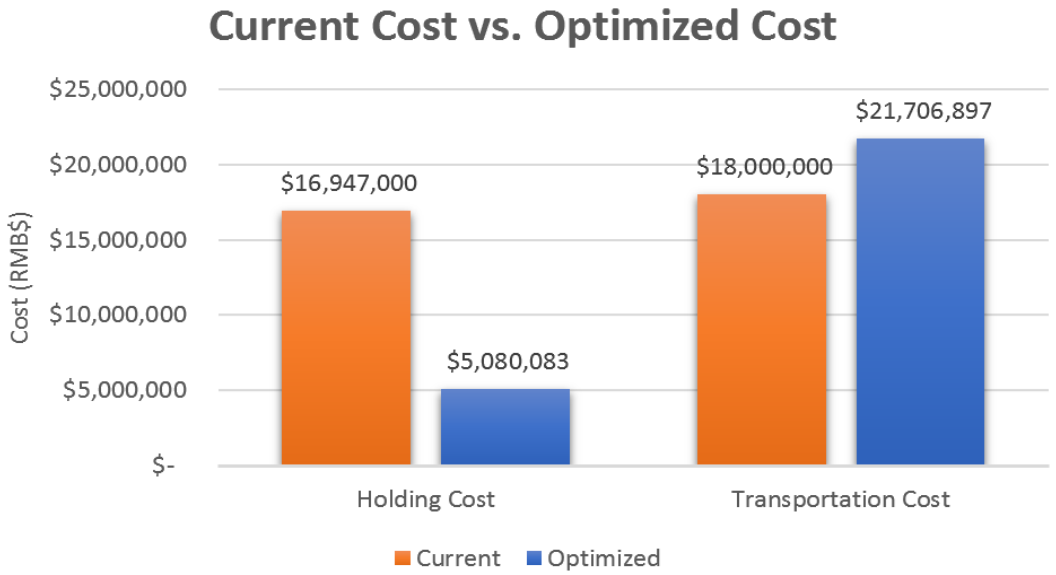
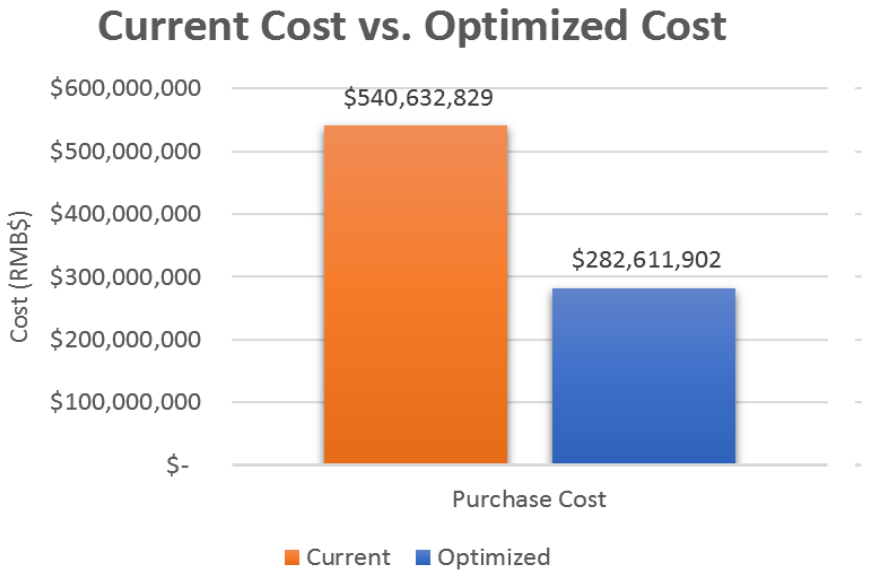
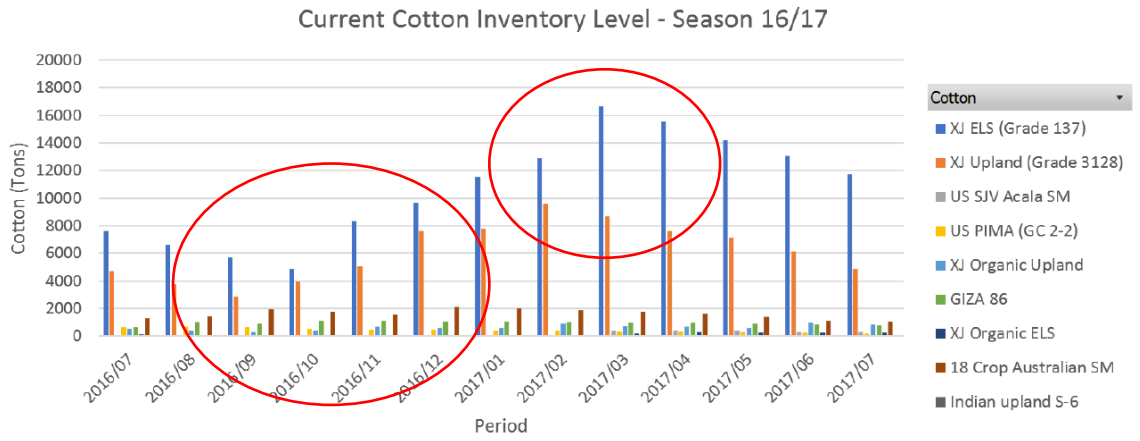


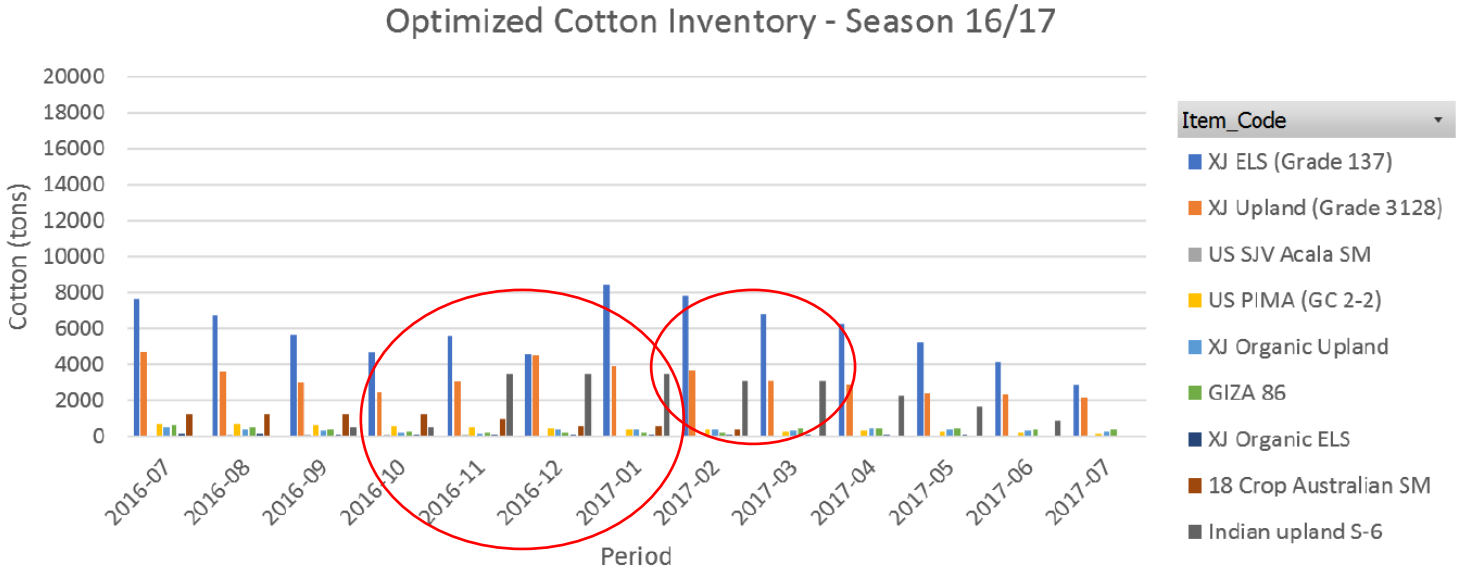


Season 16/17	Current Cost (RMB$,000)	Optimized Cost (RMB$,000)
Ordering Cost	1.9	2.9
Holding Cost		
- Cotton	16,947	4,000
- Yarn		1,080
Transportation Cost		
- Cotton	18,000	7,400
- Yarn		14,306
Total Logistics Cost	34,948.9	26,788.9

Total Logistics Cost Reduction:
RMB 8.16 MM (-23%)
USD 1.28 MM

Insights: Replenishment Decision





Insights:

- Early Replenishment of Cotton at Oct for both ELS & Upland
  - ELS cotton (Jan 2017)
  - Upland cotton (Evenly)

- 16K tons of cotton repository (way higher than 3-5 months safety stock)
  - ELS cotton (max: 9k tons)
  - Upland cotton (max: 5k tons)

Conclusion

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- MILP optimization provides a good reference for the material sourcing manager in yarn manufacturing industry to determine the time and quantity of cotton shall be replenish balancing both spot price and logistics cost considerations.
- For Cotton with high seasonality where its available are normal focus on the first 6 months, inventory shall be build around January.
- For Cotton with low seasonality where its can be available throughout the year, inventory shall be kept based on the demand and safety stock policy.
- Through optimizing the allocation of cotton based on the demanding spinning mills, cross-warehouse transfer of cotton is minimized.

Contributions

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- Proved that the conventional sourcing practice can leads to an excessive inventory of materials (opportunity cost in working capital and space) and imposed a huge logistics cost (warehouse rental cost)
- Bridge the gap of MILP Research with the industry-specific considerations and constraints (e.g. government policy, safety stock policy of cotton, cotton mixing)
- A quantitative optimization tool is built for the yarn manufacturers in this industry to adopt and review their logistics and warehouse management practice.

Future Extension

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- Other KPI for consideration: Supply Chain Sustainability; Storage Risk KPI
- Trade-off in production plans

Q&A

Appendix

Facts about Cotton / Yarn

- Cotton is a seasonal commodity.
- Cotton Season:
  - US/India/China/Brazil (Aug – Jan)
  - Australia (May – July)
- Yarn Complexity:
  - Cotton Type: Extra-Long Staple / Long Staple / Upland / Organic
  - Cotton Properties: > 7 (Strength, Length, Micronaire, Color, …)
  - Mixing: Cotton type + Balanced cotton properties
- Yarn recipe is proprietary.