Weekly presentation SCM research

11th presentation: Safety Stock Placement in Supply Chain Design

(Graves and Willems 2003)

Introduction

Traveling : *discovering the wonders of beautiful Japan and japanese society*







Introduction

But also working on interesting SCM topics!

- *Installing the useful softwares and settling the working environment for computing*
- *Getting to know gurobi, python, latex*
- *Practicing with some tutorials on the internet*
- *Still need more time to master these tools*

Objective *: apply the Graves and Willems method for Supply Chain Configuration problem*

Introduction

Safety Stock Placement in Supply Chain Design*(Graves and Willems ,2003)*

Supply chain design decisions

- *traditional(number/location/sizing of facilities, general logistics strategies)*
- *product design(topology and key economics of the SC)*
- *how to be reponsive to uncertainty and variability*

➢ *Deployment of Inventory as Safety Stock for addressing demand uncertainty*

Where are the best places in the SC to position a SS; and how much is needed to protect the chain?

Summary

I/ Context

II/ Models definition

III/ Models formulation

IV/ An example from the heavy industry

I/ Context

Comparison of two approaches to optimizing SS levels in multi-echelon SC

Stochqstic-service model

Guaranteed-service model

Network representation of the SC

Each stage is a candidate location for SS placement

Decentralized control

II/ Models definition

Stochastic-service model

Assumes the delivery or service time between stages can vary bsed on the material availibility at the supplier stage

- *Each stage maintains a SS sufficient to meet its service level target*

- *Considering a stochastic delay in case the upstream suppliers do not meet demand demand request immediately from stock*

How to characterize replenishment times given that a stage might have multiple unreliable suppliers?

II/ Models definition

Guaranteed-service model

Assumes that each stage can quote a service time that it can always satisfy

•*Each supplier must hold enough inventory to always be able to satisfy the service-time commitment*

•*Demand is bounded*

How to determine the best choice of service-times within the SC that minimize the total SC inventory and meet the service requirements for the end-customer?

III/ Models formulation

Single-stage base-stock policy

Common underlying review period

Demand is stationary and independent, with mean demand per period μ and a standard deviation σ

III/ Models formulation

Stochastic-service model

Service level target: upper bound on the probability that a stage is out of stock in any period

for external customers, dictated by the market

for internal customers, decision variable

Replenishment time at stage j :

$$\tau_i = L_j + \max_{i:(i,j)\epsilon A} \{\Delta_i\}$$

Worst case: $\tau_i = L_j + \max_{i:(i,j)\epsilon A} \{\tau_i\}$

III/ Models formulation

Stochastic-service model

• $2^N - 1$ *combinations of suppliers that might be out of stock in any period*

- *we assume that at most one supplier will stock out per period (ref to Ettl et al.2000)*

• *Expected replenishment time at stage j:*

$$E[\tau_j] = L_j + \sum_{i:(i,j)\epsilon A} \pi_{ij} L_i$$

With π_{ij} *the probability that in a period stage i is causing a stock-out at stage j*

• *Demand over replenishment time normally distributed*

III/ Models formulation

Stochastic-service model

Expected on-hand inventory for stage j:

$$E[I_j] = k_j\sigma_j\sqrt{E[\tau_j]} + \sigma_j\sqrt{E[\tau_j]}\int_{z=k_j}^{\infty}(z-k_j)\phi(z)dz$$

Expected inventory level at stage j

expected number of shortages or backorders

Where:

- *kj : safety factor necessary to achieve the service level target*
- *E[τj] : expected replenishment time*
- *ϕ() : probability density function for a standard normal*

III/ Models formulation

Guaranteed-service model

•*Same model used in Graves and Willems 2000*

•*Each stage will quote a delivery time to its downstream customers, who know that this commitment will be met with certainty*

• *Dj(t) : represents the maximum demand over t consecutive period*

•*Net replenishment time considered*

III/ Models formulation

Guaranteed-service model

•*Total cost of the safety stock in the supply chain :*

$$C^{gsm} = \sum_{j=1}^{N} C_j^s \sigma_j \sqrt{s_j^{in} + L_j + s_j^{out}}$$

•*With :*

$s_j^{in} + L_j + s_j^{out}$ *: the net replenishment time*

IV/ Example

Heavy industry :

Bulldozer assembly and manufacturing

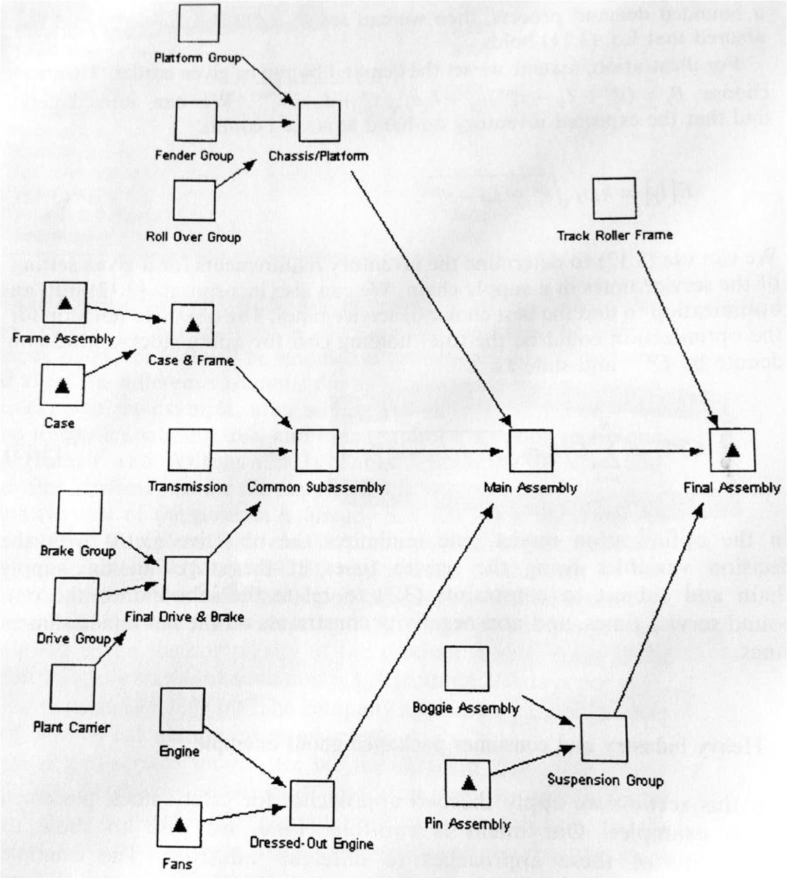

Fig. 1. Bulldozer Supply Chain Map.

IV/ Example

- *Total cost of a bulldozer*
  $72,600
- *Low lead-times*
- *Average daily demand*
  5
- *Standard deviation*
  3
- *COGS*
  $94,380,000
- *Annual holding rate*
  30%

Table 1
Parameters for Bulldozer Supply Chain

Stage name	Nominal time	Stage cost ($)
Boggie assembly	11	575
Brake group	8	3850
Case	15	2200
Case & frame	16	1500
Chassis/platform	7	4320
Common subassembly	5	8000
Dressed-out engine	10	4100
Drive group	9	1550
Engine	7	4500
Fans	12	650
Fender group	9	900
Final assembly	4	8000
Final drive & brake	6	3680
Frame assembly	19	605
Main assembly	8	12,000
Pin assembly	35	90
Plant carrier	9	155
Platform group	6	725
Roll over group	8	1150
Suspension group	7	3600
Track roller frame	10	3000
Transmission	15	7450

IV/ Example

Guaranteed-service model

- *Safety factor*
  k = 1.645
- *Net replenishent time at final assembly*
  28 days
- *Annual holding cost for SS*
  $633,000
- *Uneconomical to develop local decoupling points*

Table 2
Optimal Service Times and Safety Stock Costs under Guaranteed-Service Model

Stage name	Service time	Stage safety stock cost ($)
Boggie assembly	11	0
Brake group	8	0
Case	0	12,614
Case & frame	15	6373
Chassis/platform	16	0
Common subassembly	20	0
Dressed-out engine	20	0
Drive group	9	0
Engine	7	0
Fans	10	1361
Fender group	9	0
Final assembly	0	607,969
Final drive & brake	15	0
Frame assembly	0	3904
Main assembly	28	0
Pin assembly	21	499
Plant carrier	9	0
Platform group	6	0
Roll over group	8	0
Suspension group	28	0
Track roller frame	10	0
Transmission	15	0

IV/ Example

Stochastic-service model

- *Service level set as a decision Variable*
- *Service levels lb for*
  - ***0.80** for more than 3 suppliers*
  - ***0.68** for one or two suppliers*
- *Every stage carries SS*
- ***12% more inventory cost***

Table 3
Nominal and Expected Lead-times for the Stochastic-Service Model

Stage name	Nominal lead-time	Service level (%)	Expected lead-time	Stage safety stock cost ($)
Boggie assembly	11	68	11.00	1160
Brake group	8	80	8.00	9342
Case	15	68	15.00	5181
Case & frame	16	80	24.24	18,184
Chassis/platform	7	80	10.29	19,521
Common subassembly	5	80	10.29	79,764
Dressed-out engine	10	80	14.61	30,328
Drive group	9	80	9.00	3989
Engine	7	68	7.00	7240
Fans	12	68	12.00	1369
Fender group	9	80	9.00	2316
Final assembly	4	95	7.57	299,472
Final drive & brake	6	80	9.71	24,693
Frame assembly	19	68	19.00	1604
Main assembly	8	80	11.14	164,194
Pin assembly	35	68	35.00	324
Plant carrier	9	80	9.00	399
Platform group	6	80	6.00	1524
Roll over group	8	80	8.00	2791
Suspension group	7	80	18.15	15,589
Track roller frame	10	80	10.00	8139
Transmission	15	80	15.00	24,754

IV/ Example

Comparison

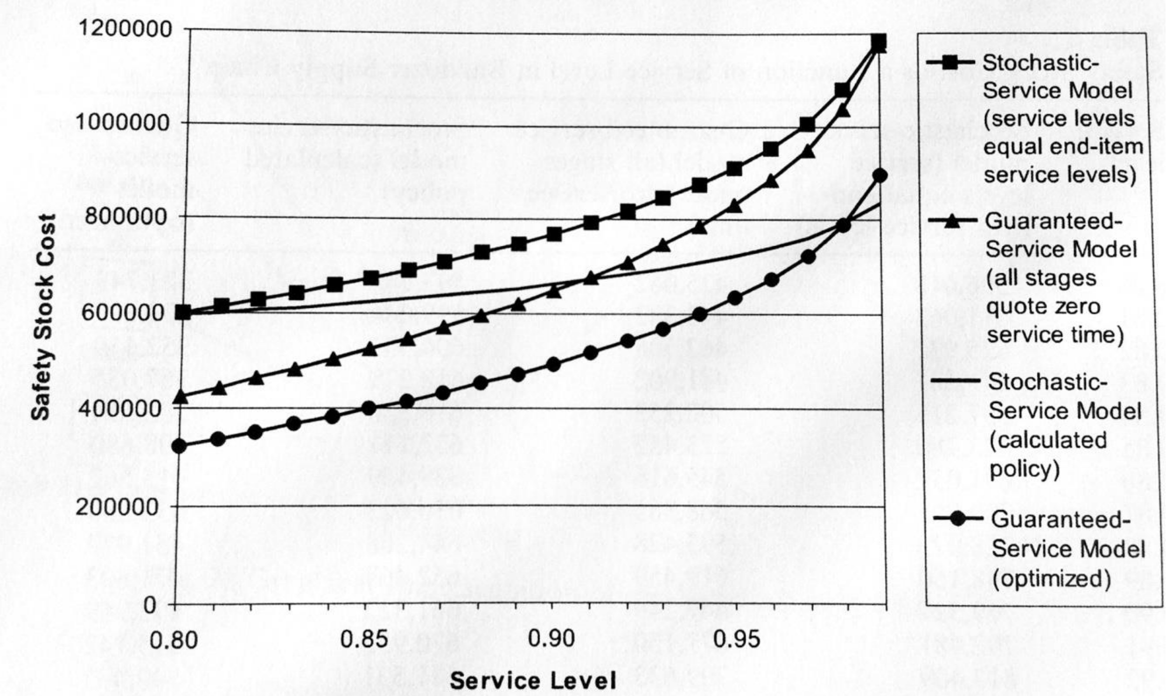

Fig. 2. Safety Stock Cost as a Function of Service Level in Bulldozer Supply Chain.

Next steps

- *Latex assignment*
- *Keep on doing tutorials on gurobi*
- *Trying to implement the Graves and Willems model*
- *Considering new readings (especially in the Supply Chain Design handbooks)*
  - *getting better knowledge on SCD and eventually focusing in the end on the SCC problem from Graves and Willems*

Thank you for your attention