Systems Aspects of Supply Chain Management
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Stuart J. Kretch
314.283.4696 (m)
Stuart.Kretch@gmail.com

Agenda

- Supply Chain Definitions and Issues
- Supply Chain Architecture
- Supply Chain Mathematics

Supply Chains and The Systems Engineering Processes

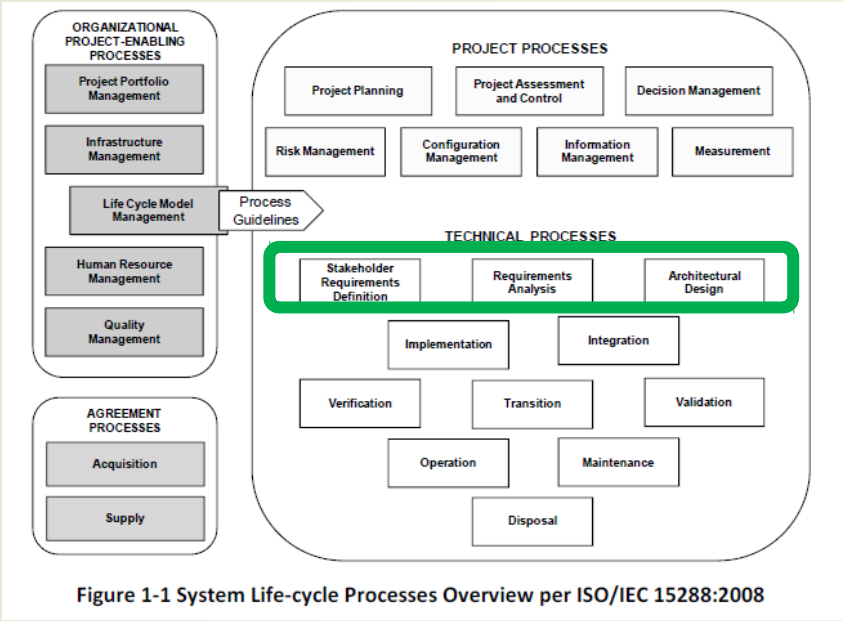
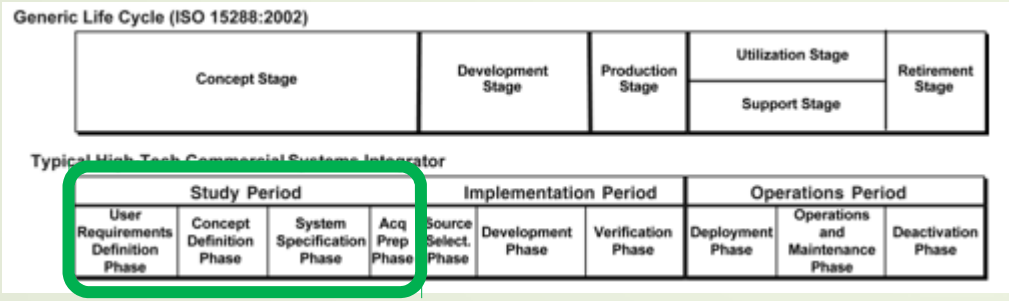


Figure 1-1 System Life-cycle Processes Overview per ISO/IEC 15288:2008

The INCOSE
Systems Engineering Processes



The INCOSE
Systems Engineering Lifecycle

Typical Supply Chain Methodology and Framework

- Strategic Analysis and Definition
  - Pre-Implementation
  - Where do facilities, processes and capacity reside?
  - Is project feasible and financially sound?
- Tactical Planning
  - Post-Implementation
  - What orders are processed and generated when and where?
- Operational Control
  - Post-Tactical Planning
  - What work centers/stations/resources are assigned to orders and when
  - Assign capacity to work orders

What Does a Supply Chain Look Like?

Outside Suppliers

Enterprise

Customers















Supply Chain Data

- Raw Materials
- Finished Goods
- Locations
- Inventory of Raw Materials, Finished Goods
- Lead-Times of Sourced Material
- Bill of Materials (BOM)
- Transit Times
- Production Capacities
- Costs and Revenues
- Orders

Issues in Supply Chains

1. Objective: Have the right Finished Goods available to sell at the right location at the right time to minimize Stock-outs
2. Objective: Have the right Raw Materials for production when and where you need them (their absence can violate #1 above)
3. Objective: Minimize Finished Goods and Raw Material Inventories to minimize costs
4. Common Tactic: Increase Inventories of Finished Goods and Raw Materials to buffer against uncertainties
5. Common Tactic: Maximize utilization to minimize costs
6. Result: By using *ad hoc* planning, Inventory buffering is excessive. Sometimes, the excess is enormous

Issues in Supply Chains

- Bottlenecks put an upper limit on a Supply Chain's capacity to produce
- Bottlenecks are not always visible or intuitive except in their effect
- Bottlenecks always exist. They may not constrain output if demand is below capacity utilization

Issues in Supply Chains

- Finite Capacity Planning determines how much can be produced
- Finite Capacity Planning is hard; companies often used to use Infinite Capacity Planning.
  - It gives an answer, but it's usually wrong

Demand Forecast

- Generate a Forecast of Shipments by Finished Goods, Time Bucket and Location
- Forecast based on historical sales
  - Occasionally other exogenous variables are included, e.g. interest rates, inflation, etc.
- Forecast includes
  - Mathematically calculated
  - Historical Sales
  - Forecast Netting to avoid double counting actual sales
- Forecast is then reviewed and adjusted manually yielding consensus forecast

Strategic Plan

- Assessing whether to build/divest a plant, warehouse or distribution center
- Need to know if the new arrangement will be feasible and profitable
- Need to know, for instance, where to locate new facilities or which existing facilities to divest

Strategic Plan

- Typically a multi-year plan aggregating work by month
- Used to assess operational and financial feasibility
- Used to decide whether to build and operate facility within or construct a Supply Chain

Tactical Plan

- Plan across Facilities, Finished Goods and Time Periods
- Plan tells what is going to be produced, procured, shipped, stored in inventory, etc.
- Produce Plan that is *feasible* – one which satisfies all constraints including Capacity and specific Demand
- Produces a plan that is optimal according to business rules and mathematical optimization

Tactical Plan

- Typically a multi-month plan of day-to-day work
- Used to assess when and where work is to be performed to align sales, logistics and manufacturing
- Used to execute within a Supply Chain

Operational Plan

- Typically a multi-week plan of Day-to-Day and Minute-to-Minute operations
- Used to direct work
- Multi-month detailed plan of operation used to drive out a plan for each facility
- Often known as 'Schedule'
- Specifies which production, shipping and other orders are to be processed, when and with what resources

Input to Tactical Planning

- Demand Forecast
- Inventory of Raw Material and Finished Goods
  - Inventories
  - In-Transit
  - On Order
- Materials, Capacities and Constraints, Routings/Recipes, Lead-times, Vendors, Locations, Costs and/or Prices

Tactical Plan Model Elements

Supplier Warehouse	Supplier may or may not Warehouse
Truck Transportation	Could be other Transportation Modes, e.g. Air, Ship, Rail.
Manufacturer	Assumed discrete Industrial or CPG Manufacturer
Truck Transportation	Could be other Transportation Modes, e.g. Air, Ship, Rail.
Customer (either Retail or Industrial)	Assumes Implied Customer Warehouse

Supplier and Warehouse

Supplier

Description

Enterprises procure Raw Materials for use in Manufacturing. They may also procure Finished Goods for resale or through outsourcing. Procurement must account for Cost and Lead-Time to satisfy financial requirements and to make sure that materials are available when needed.

Data

Material (or Services)
Demand (D_P)
Lead-Time (LP)
Cost
Location

Equations

Reorder level = $L_P \times D_P$ (in days)

Warehouse

Warehouse

Description

Safety Stock is used to handle fluctuations and uncertainty in the need for materials from the Warehouse.
There is no universal formula for safety stock. The particular equation used is determined by business requirements, e.g. does lead-time change, does demand change?

Data

Material
Lead-Time (L)
Standard Deviation of Leadtime (σ_{LT})
Service Level (Z)
Demand (D_{avg})
Daily Usage (U_{max})
Daily Usage (U_{Avg})

Equations

$$\text{Safety Stock} = Z \times \sigma_{LT} \times D_{avg}$$

Production Facility

Production Facility

Description

Manufacturing is performed to fulfill work orders. Raw Material is consumed and transformed into Finished Goods. The mapping of Finished Goods onto Raw Materials is defined by the Bill of Materials (BOM).

Data

Material
Bill of Materials
Inventory at Time t(I_t)
Inventory at Time t-1(I_{i-1})
Demand (D)
Routing or Recipe
Work Center
Capacity
Location

Equation

Planned Production in Units = $D + I_t - I_{i-1}$

Freight Transportation

Freight Transportation

Description

A common problem is how to ship product from different warehouses and factories to Customers. Freight Costs reflect distances and Transportation Modes.

Data

Demand
Locations
Costs

Equation

Optimize via LP solver:

- Demand ≥ 0
- Total Received ≥ Demand
- Total Shipped ≤ Capacity
- Minimize Aggregate Transportation Costs

Supply Chains and The Systems Engineering Processes

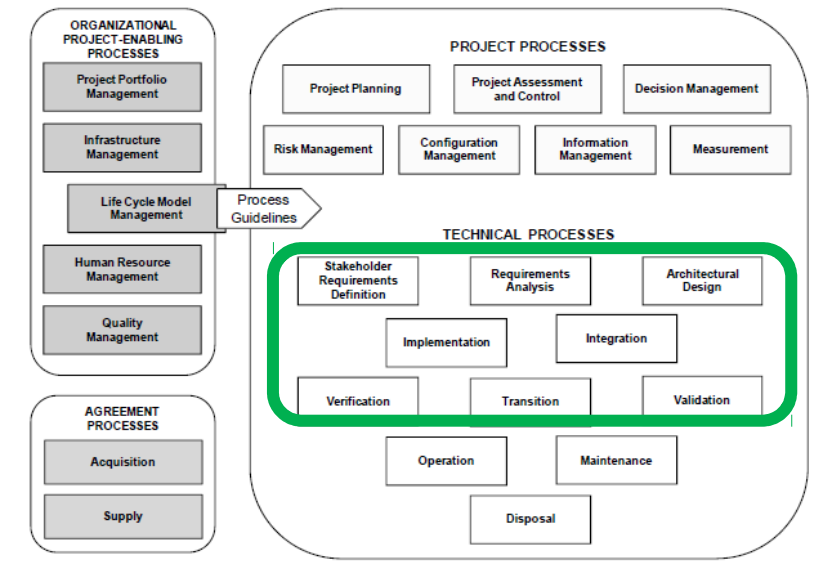


Figure 1-1 System Life-cycle Processes Overview per ISO/IEC 15288:2008

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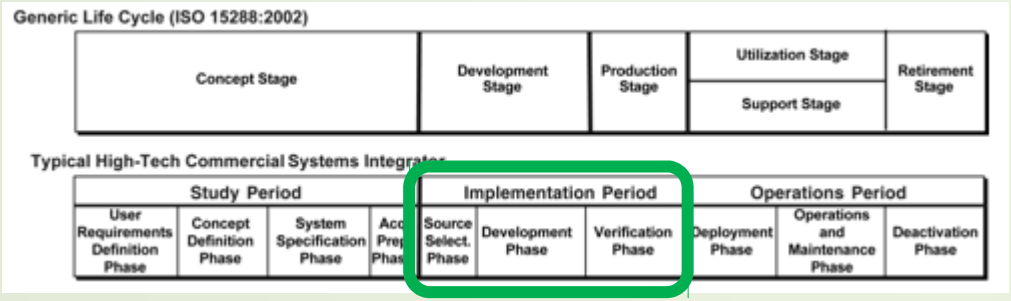

The INCOSE
Systems Engineering Lifecycle

Improving Efficiency

Many strategies exist to improve efficiency, e.g.

- Warehouse Operations – automation, cross-docking
- Factory Operations – automation, fixed vs. flexible automation
- Run strategies – reduce setup times
- Maintenance Management – reduce downtime and dramatically reduce unplanned downtime

Optimization

Planning Module uses Forecast, Model and Data in Planning Module to generate an optimal planning solution telling what, where and when to

- Procure Raw Materials and Finished Goods
- Transport Raw Materials and put them into Inventory
- Manufacture Finished Goods
- Put Finished Goods into Inventory, and
- Ship Finished Goods to Customers

Optimization

- Satisfy constraints to, e.g.
  - Procure Raw Materials and Finished Goods
  - Transport Raw Materials and put them into Inventory
- The Objective Function
  - Minimizes cost or,
  - Maximizes profit or revenue
- Calculation is done via Linear Programming and a Mixed Integer model

Optimization

- Solutions can take hours to generate
- Solving the optimization problem operates over large amounts of operational data using and generating more
  - Customer Orders
  - Production Orders
  - Replenishment Orders
  - Etc.

  Across all SKUs, all facilities, all locations, etc.

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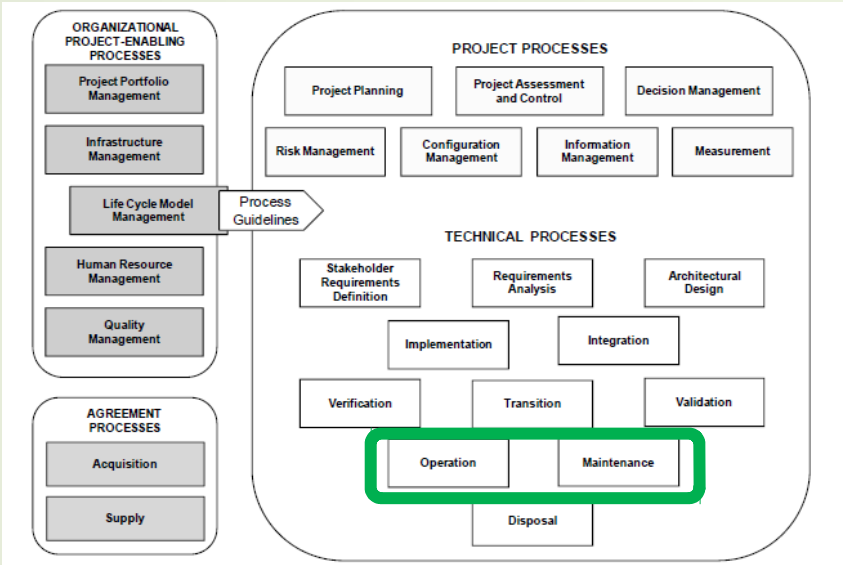

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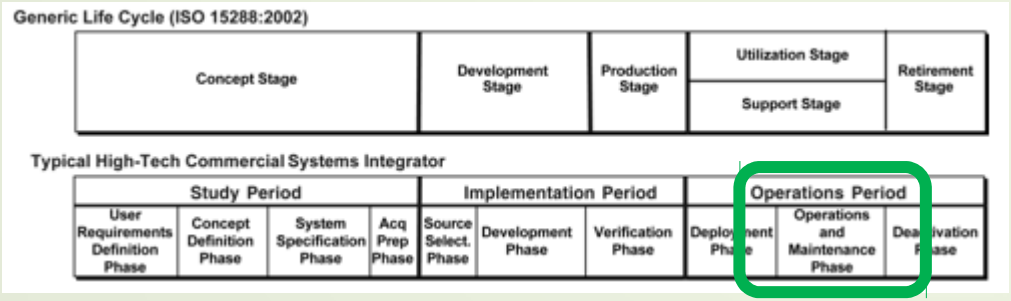

The INCOSE
Systems Engineering Lifecycle

Operational Plan

- Procurement Plan
- Inventory Plan
- Transportation Plan
- Demand Plan
- Deployment Plan
- Sales & Operation Plan (S&OP)
- Drives the hour-to-hour/minute-to-minute schedule

Does Supply Chain Management Work?

- **YES!** It synchronizes the *entire Supply Chain* with Demand and all its components AND it synchronizes the different Supply Chain processes with each other
  - Synchronization is in magnitude, time, location and type of Demand
  - Synchronization appears operationally and financially
- It reduces Inventory and improves Service
- It reduces costs and increases Revenues

What Can Go Wrong?

You have to

- Be able to forecast. If your forecast is off, plans are at risk
- Have an effectively running operation. If your operation is broken, Supply Chain Management may not fix it
- Adhere to plans. If you circumvent a plan, something is going to break elsewhere. '701 Problem'

What Can Go Wrong?

- Processes and resources have to be reliable However,
  - An effective Maintenance Management program can perform maintenance work via work orders that become part of the overall plan and flow through the system
  - This increases Reliability
- Staff – including C-Suite – must align their incentives to be consistent with the new operation. If not, there is risk they will drive people to violate plans

Questions?