MITx | MicroMasters™
in Supply Chain Management

MIT Center for Transportation & Logistics

CTL.SC4x – Technology and Systems

Key Concepts Document

This document contains the Key Concepts for the SC4x course.

These are meant to complement, not replace, the lesson videos and slides. They are intended to be references for you to use going forward and are based on the assumption that you have learned the concepts and completed the practice problems.

The first draft was created by Dr. Alexis Bateman in the winter of 2017.

This is a draft of the material, so please post any suggestions, corrections, or recommendations to the Discussion Forum under the topic thread "Key Concept Documents Improvements."

Thanks,

Chris Caplice, Eva Ponce and the SC0x Teaching Community
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Supply Chain Systems: Enterprise Resource Planning

Summary

In this next segment, we explore supply chain IT systems. Because supply chains are essentially made up of three flows: information, material, and money – IT systems support the information flow. For example, in a supermarket, they have to deal with different types of supply chain data such as supplier inventory, facility management and payroll, sales, and expired and obsolete inventory. There are many daily transactions in a supermarket that need to be captured and ensured for consistency and timeliness. That information needs to be somehow translated into usable information for business decisions, and then these objectives need to be efficiently achieved. The amount of information for transactions per week in a single supermarket can number in the millions. This is for a single store.

On an enterprise level, companies need systems that help them manage and organize this information for use. While supply chains are always portrayed as neat and linear systems, the reality is much different, as we have learned over the previous courses. Flows move up and down the chain and through many partners until they reach their final destination. Supply chains need IT systems because while teams may sit in different functional units they frequently need to share information. In addition, many different firms interact in the supply chain, they need systems to carry that information between them, this helps de-silo the supply chain. There needs to be coordination across functions, which is the essence of supply chain management and can be facilitated with systems like Enterprise Resource Planning (ERP).

Supply Chain IT Systems

Supply chains need IT systems because they are large, complex and involve many players. They often become intertwined and individual actors impact others. Decision-making is based on common data and interaction with other functions in a firm. And supply chains need IT systems because supply chains require communication for so many interactions B2B, B2C, M2M, etc. (B2B = business to business, B2C = Business to Consumer, M2M = machine to machine)

Enterprise Resource Planning (ERP) systems serve as a general ledger and central database for all firm activity. The next are **Supply Chain Planning Systems**. These systems are primarily for production planning and scheduling, demand planning and product lifecycle management. The last are for **Supply Chain Execution**; which are transportation and warehouse management systems and manufacturing systems. The first we will tackle are Enterprise Resource Planning systems.

Enterprise Resource Planning

In the following section we cover why firms use ERPs; the core functions of ERPs; data needed; communications of the systems; and strategic benefits of an ERP. Most firms have an ERP because many functions in a firm such as sales, inventory, production, finance, distribution, and human resources have siloed databases. With a centralized ERP, these databases can more easily be exchanged and shared.

Benefits of ERP allow enterprises to organize processes and data structure, integrate information into unified repository, make data available for many users, eliminate redundant systems and data, reduce non-value added tasks, standardize process designs, as well as be more flexible. There are significant drawbacks to using ERP, these include: significant implementation time and maintenance that come at a cost, data errors ripple through systems, competitive advantage can be dampened, firm reliance on a single vendor, shortage of personnel with technical knowledge of system, and high impact of down time of said system.

ERP Core Functions

Most ERP Systems share the same core functions. They tie together and automate enterprise-wide basic business processes:

Customer Management is the face to consumers and serves the following functions:

- enables order entry, order promising, open order status
- allows marketing to set pricing schemes, promotions, and discounts
- provides real-time profitability analysis, and
- permits order configuration, customer delivery schedules, customer returns, tax management, currency conversion, etc.

Manufacturing is the face to production and serves the following functions:

- includes MRP processing, manufacturing order release, WIP management, cost reporting, shop floor control etc.,
- provides real time linkage of demand to supply management enabling real time Available-to-Promise (ATP) & Capable-to-Promise (CTP), and
- serves as primary interface to “bolt-on” advanced planning and scheduling optimization modules.

Procurement is the face to suppliers and serves the following functions:

- integrates procurement with supplier management,
- facilitates purchase order processing, delivery scheduling, open order tracking, receiving, inspection, and supplier performance reporting, and
- creates requests for quotation (RFQ)
- manages negotiation and pricing capabilities.

Logistics is the face to internal and external supply chain and serves the following functions:

- runs the internal supply chain for enterprise,
- provides connectivity to remote trading partners (3PLs, carriers, etc.),
- handles distribution channel configuration, warehouse activity management, channel replenishment, planning, distribution order management, etc., and

- serves as primary interface to “bolt-on” warehouse and transportation management systems (WMS and TMS).

Product Data is the face to all material and serves the following functions:

- describes products enterprise makes and/or distributes,
- contains proprietary data on costs, sources, engineering details, dimensions, weight, packaging, etc.,
- interfaces with inventory, manufacturing, and product lifecycle management, and
- sometimes included in partner collaborations in order to compress time to market of new products.

Finance is the face to the CFO and serves the following functions:

- strong suit of most ERPs (but also a double edged sword!),
- provides real-time reporting of all transactions resulting from inventory movement, accounts receivable, accounts payable, taxes, foreign currency conversions, and any other journal entries, and
- supports detailed reporting and budgeting capabilities.

ERP Data

There are three types of ERP Data:

Organization data: represents and captures the structure of an enterprise.

Master data: represents entities (customers, vendors) with processes. It is the most commonly used. But because specific processes use materials differential and specific data needs differ by processes – this adds to complexity of master data needs. Material types can be in different states and can be grouped differently based on firm needs.

Transaction data: reflects the outcome of executing process steps. It comes in organizational, master and situational data. Transaction documents include purchase orders, invoices, etc.

ERP Communication

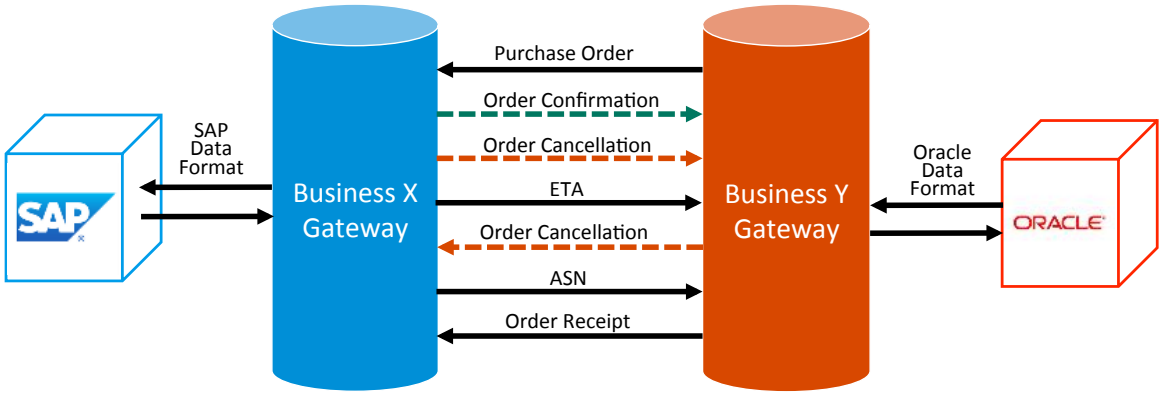
Business-to-Business (B2B): Commerce transactions between manufacturers, wholesalers, retailers. Each business represents a link in the supply chain.

Business-to-Customer (B2C): Sale transactions between firms and end-customers. The volume of B2B transactions is much greater than B2C.

Accelerating and validating B2B and B2C transactions: For B2B this is achieved through Electronic Data Interchange (EDI). For B2C this is achieved through a website and email.

Electronic Data Interchange (EDI): “The computer-to-computer interchange of strictly formatted messages that represent documents other than monetary instruments.” There is no human intervention in the process.

ERP systems can “communicate” via EDI, sharing near real-time information. See figure below.



The Value of ERP for SCM

There are three important values of ERP for supply chain management: reduction of the bullwhip effect, enabling widespread analytics, and extending the enterprise.

Reducing the Impact of Bullwhip Effect

One of the key values of an ERP system is reducing or preventing the Bullwhip Effect. **The Bullwhip Effect** is phenomenon where information distortion leads to increasing order fluctuations in the upstream supply chain (forecast-driven supply chains). It is driven by several behavioral causes like overreaction to backlogs and lack of transparency. There are also many operation al errors such as forecasting errors, lead-time variability, and promotions.

ERP can reduce the impact of the Bullwhip Effect by extending visibility downstream to customer demand and upstream to participations enabling collaboration and information sharing. It also facilitates point of sale capturing and helps reduce batch size and demand variability through smaller and more frequent orders.

Enabling Analytics

ERP systems play a key role in enabling analytics. They are primarily retrospective, serve as the ledger of the firm, and provide the CFO with financial snapshots. They also enable other forms of analytics for **Business Intelligence (BI)**: which transforms raw data into meaningful information to improve business decision-making. These can be descriptive, predictive, and prescriptive.

Extending Enterprise

While ERP systems are primarily used in intra-firm process management to connect various departments and provide access to data, they also serve an extending function for better connection with partners. ERPs serve a value in connecting End to End Supply Chains with better connections across SC participants, providing shared understanding, reducing coordination and monitoring costs, and responding quickly to market feedback.

Learning Objectives

- Introduction to supply chain IT systems, their value, application, and constraints.
- Review ERP, its setup functionality, and applications.
- Recognize core functions of ERP.
- Be familiar with data house in ERP systems.
- Review how that data is used to facilitate communication.
- Understand some of the value of ERP systems for supply chains.

Supply Chain Modules

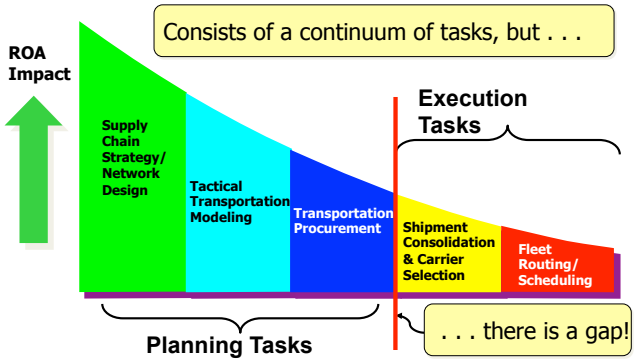
Summary

In this next segment we review different supply chain modules as a subset of supply chain IT systems. To understand where we are now with supply chain IT systems – we need to review the evolution of supply chain tools. We journey from the 1960-70's with the Bill of Materials Processor, mainframes based database systems, and material requirements planning (MRP) to the 1980's with the second coming of MRP that added finance and marketing, Just-In-Time manufacturing methodology, expansions to other function, and the precursor to the ERP systems of today. In the 1990s, most MRP systems were absorbed into ERP suites; there was the introduction of Advance Planning Systems (APS), and wider adoption of ERP systems. In the 2000s, many of these systems adopted web-based interfaces, improved communication, and adopted shared or cloud based solutions. There was also a major consolidation of supply chain software vendors and expansion of ERP systems to include SCM.

Now as we explore how to further extend the enterprise and its ability to adequately manage its information on its own and together with other companies, many firms use a series of IT modules. These systems are sometimes apart of ERP, may be standalone applications, or can be part of a larger supply chain ecosystem. We will review two main functionalities including Advance Planning Systems (APS) and Execution Applications. Advanced Planning Systems (APS) are long range, optimization based decision support tools while execution applications include Warehouse Management Systems (WMS), Transportation Management Systems (TMS), and Manufacturing Execution Systems (MES).

Planning vs. Execution

Although planning modules seek to enable future planning and enabling efficient processes, there is often a gap between the planning and execution tasks. The figure below illustrates this gap.



Questions, Approaches, and Technologies Change based on timeframe

Questions can be **strategic** such as: "What carriers should I partner with and how?" "How should I flow my products?" or they can be **tactical** such as: "How can I quickly secure rates for a new DC/plant/lane?" "What lanes are having performance problems?" or **operational**: "Which carrier should I tender this load to?" "How can I collaboratively source this weeks' loads?"

The timeframe also drives the **approach**. For instance in the strategic face – a company will be establishing a plan and strategy, have event based enablement and complete non-routine analysis. In an operational timeframe they will be executing the strategic plan, operate on transaction based rules and processes, and have automated actions.

And **technologies** also align with timeframes. For instance, strategic timeline will allow for analysis engines tools like optimization, simulation and data analysis and communication via the web, file exchange and remote access. The tactical timeline allows for the same analysis and communication technologies while the operational timeline allows for communication but also workflow software such as compliance tracking, rules, and transaction processing.

Advanced Planning Systems

We now take a closer look at advanced planning systems that are primarily used as decision support systems. They typically include functionality for network design, demand planning, production planning, production scheduling, distribution planning, and transportation planning. Advanced Planning Systems utilize large scale mixed integer linear programs (MILPs) and sometimes simulation.

Planning Horizons

Advance Planning Systems help with planning horizons. The following provide a rough guideline but each firm differs and it is unique to specific industries.:

- 3 months out – Master Production Schedule (MRP, DRP)
    - <4 weeks out - Frozen MPS
    - 5 to 8 weeks out – Slush MPS – some changes allowed (+- 10%)
    - >8 weeks out – Water MPS – more changes are allowed (+- 30%)
- 3-18 months out – Aggregated Planning
- >18 months out – Long Range Planning – Network Design, etc.

Flow

Inputs (from ERP or other systems): Current costs, manufacturing and storage capacities, consensus forecast, sales orders, production status, purchase orders, and inventory policy recommendations, etc.

Decision Process: Large scale optimization (MILP) across multiple facilities and time horizons in a single planning run; unconstrained, constrained, and optimal plans

Outputs: Demand forecast and plan for meeting demand; a feasible production plan for future periods to include allocation of production to plants; allocation of orders to suppliers; identification of bottlenecks; Root Cause Analysis.

Transportation Management Systems (TMS)

TMS is software that facilitates procurement of transportation services, short-term planning and optimization of transportation activities, assets, and resources, and execution of transportation plans (Gonzalez 2009). It is often geographic and mode specific. The core functions of TMS are: transportation procurement; mode and carrier selection; carrier communication; routing guide generation and maintenance; fleet management; audit, payment, and claims; appointment scheduling; yard management; and route planning.

Transportation Execution

The TMS serves as the interface to the carriers while connecting the Order Management System (OMS), Payment Systems, and the ERP. Its main objective is to: move products from initial origin to final destination in cost effectively while meeting the level of service meeting standards and executing the plan using the procured carriers. This is broken down in phases below:

PLAN: Create Shipments from Orders
EXECUTE: Select and tender to Carriers
MONITOR: Visibility of the status of Shipments
RECONCILE: Audit invoices and pay for Transportation

There are many considerations to be made in TMS such as:

- How do orders drop? Batched vs Continuous?
- How much time is allowed between drop and must-ship? Weeks? Days? Hours? Minutes?
- What percentage of orders change after release?
- How do they change? Quantity? Mix? Destinations? Timing?
- What is the length of haul?
- How many orders are "in play" at any time?

There are also key decisions like carrier selection and load building.

TMS Carrier Communication & Selection

Useful EDI Transaction Sets

- 204 – Motor Carrier Load Tender: Used by shippers to tender an offer for a shipment to a full truckload motor carrier. It may be used for creating, updating or replacing, or canceling a shipment.
- 990 - Response to a Load Tender: Used by motor carriers to indicate whether it will pick up a shipment offered by the shipper
- 214 - Transportation Carrier Shipment Status Message: Used by carriers to provide shippers and consignees with the status of their shipments.
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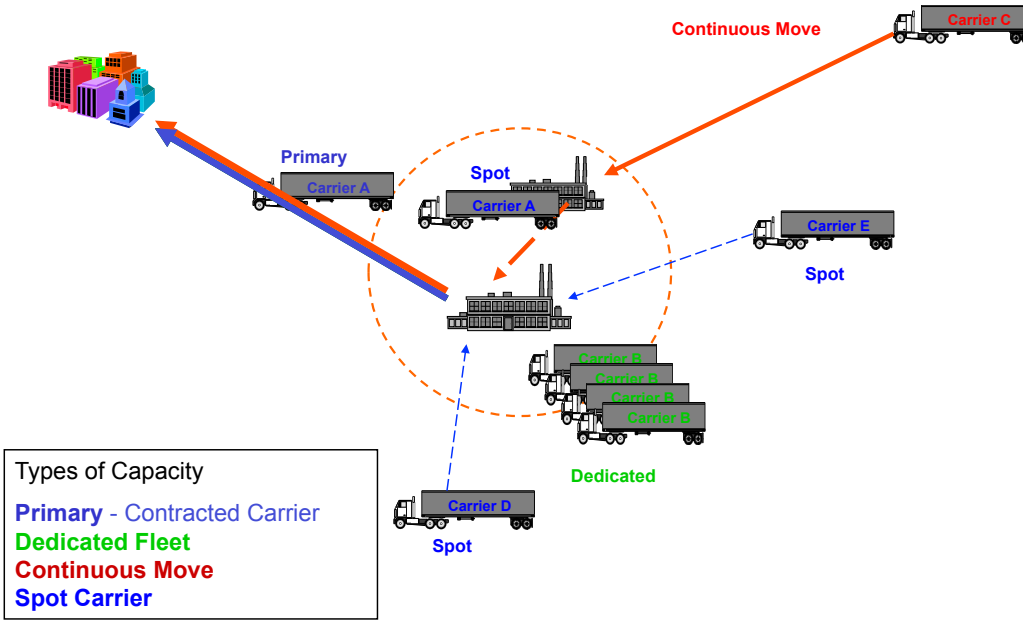
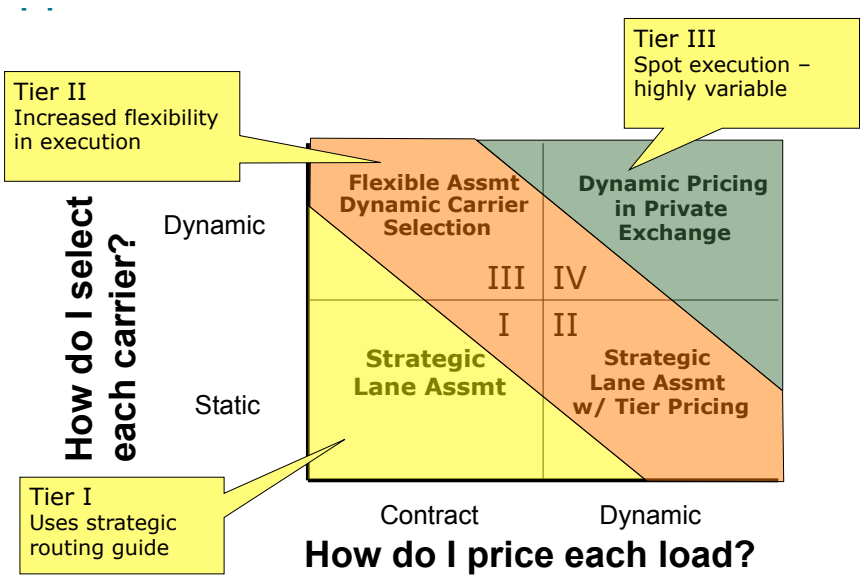
Example of carrier selection



Linking Approaches



Warehouse Management Systems & Automation

WMS is a software system that facilitates all aspects of operations within a warehouse or distribution center and integrates with other systems. It is not the same as inventory management systems; WMS complements IMS. Examples of the benefits of a WMS include: real-time stock visibility and traceability, improved labor productivity, and improved customer

service. Some of these benefits are closely tied to automation of material handling and paperless device interfaces.

Examples of Warehouse Automation include:
Automatic identification technologies: Bar codes and bar code scanners, radio frequency tags (RFID) and antennae, smart cards and magnetic stripes, vision systems.
Automatic communication technologies: Radio frequency data communications, synthesized voice, virtual displays, pick to light / voice systems
Automated material handling technologies: Carousels, conveyors/robotics, flow racks, AS/AR Systems

WMS Software Components

Order Processing

- Order checking & batching
- Allocation
- Auto-replenishment

Receiving

- ASN planning
- In bound tracking
- Delivery appointment scheduling
- PO verification
- Returns processing

Put-Away

- Palletizing
- Zoning and slotting
- Random/directed put away
- Routing for putaway & replenishment

Picking

- Batch/Wave/Zone/Directed picking
- Carton/pallet select
- Assembly/kitting
- Pick-to-light/voice

Shipping

- Pallet sequencing & Load planning
- Pallet layering
- Trailer management

Labor Management

- Individual/team performance mgmt
- Labor scheduling
- Time standards

Equipment Support

- Interface to automated equipment
- Equipment maintenance

Manufacturing Execution Systems

MES is a software system that manages and monitors all work-in-process (WIP) in the production process. It is integrated with the ERP to manage the execution of release of production orders to finished goods delivery, trigger supply chain replenishments, and enhance product traceability through manufacturing.

The functionality of a MES include:

- Machine scheduling
- Process management
- Document control
- Labor management
- Inventory management
- Product (WIP) tracking
- Performance analysis
- Labor management
- Quality management
- Production reporting

Learning Objectives

- Become familiar with systems that are common in supply chains that extend the enterprise.
- Differentiate between Advanced Planning Systems and Execution Systems.
- Recognize the gaps in planning vs. execution and the timeframes embedded in both.
- Review Advanced Planning Systems, their use and application.
- Become familiar with the main execution systems in SC such as TMS, WMS, and MES.