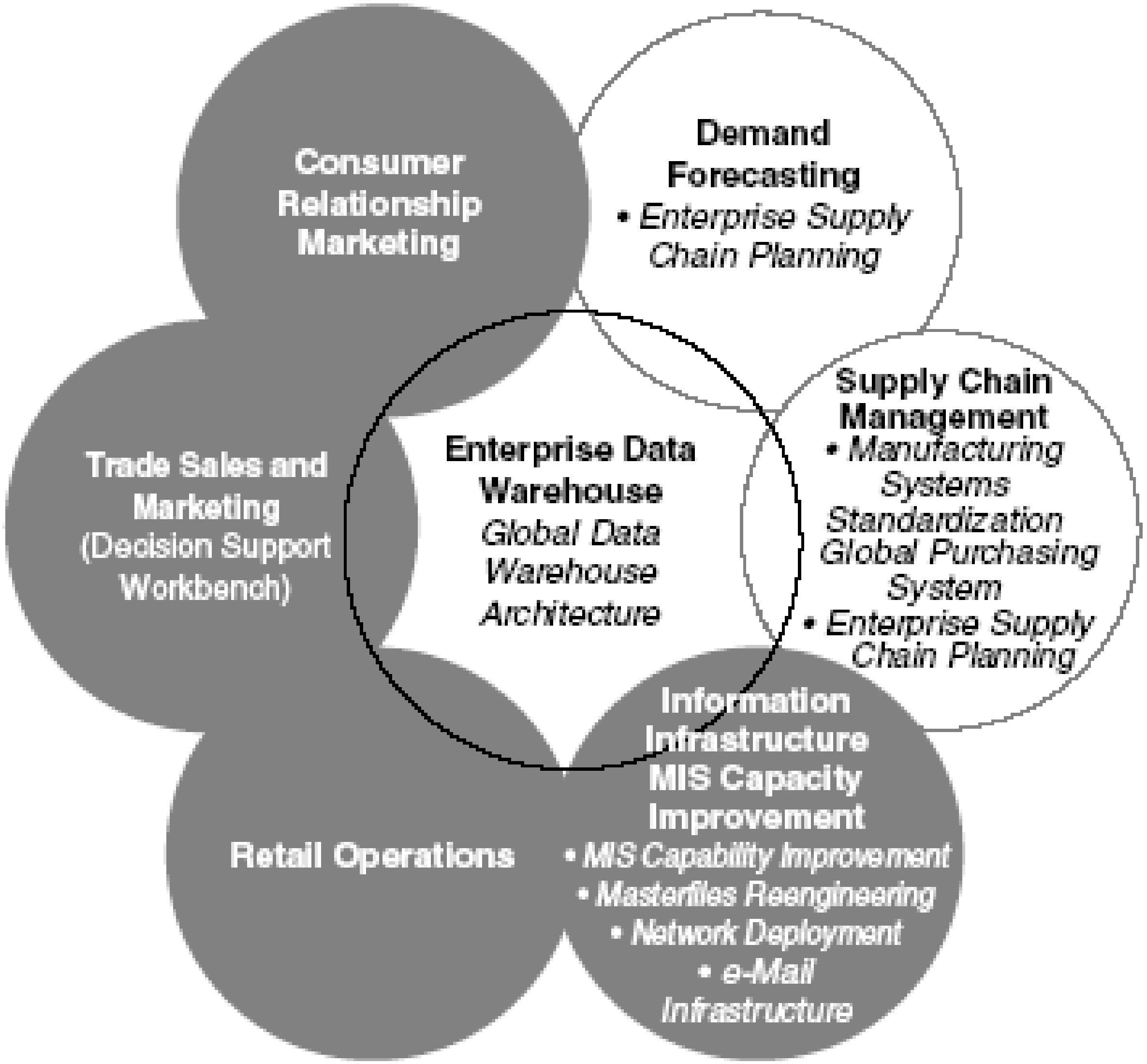
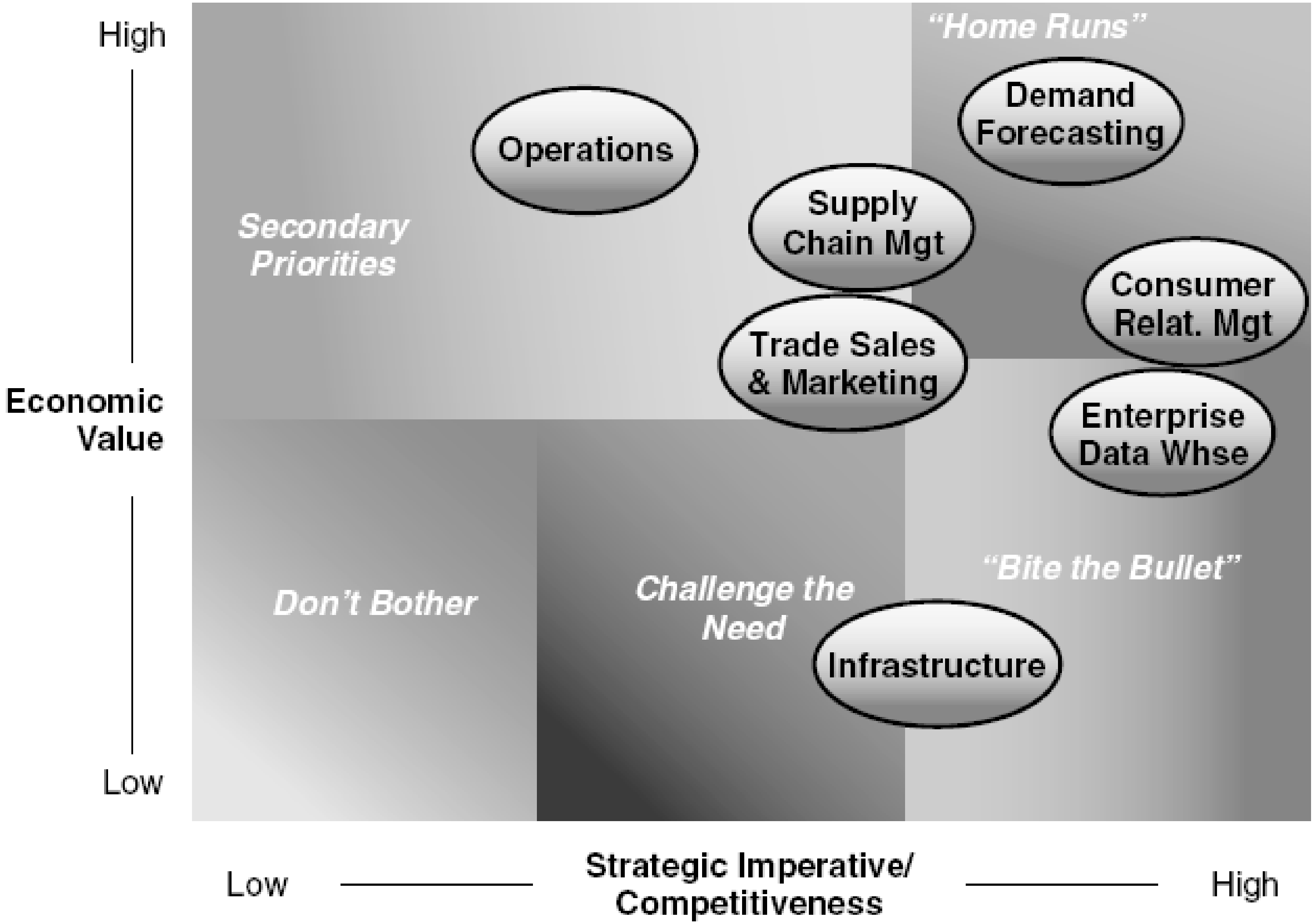
SUPPLY CHAIN , FORECASTING , DEMAND MANAGEMENT AND CAPACITY PLANNING

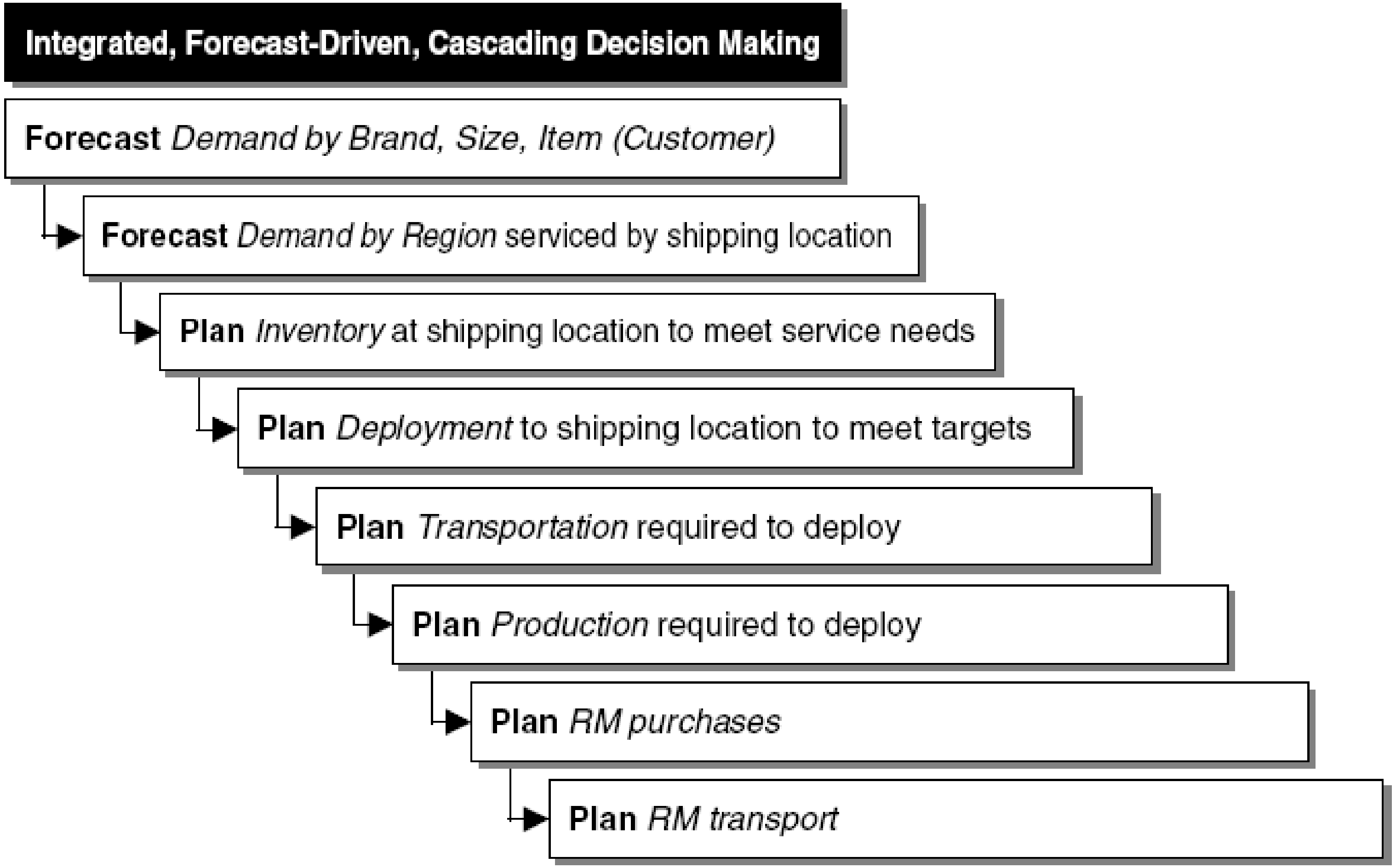
- The real purpose of this advanced collaboration is to bring a balance to
- *demand management* (caring for what is really needed in the supply chain)
- and *capacity planning* (making sure the right goods and services are available to meet the true demand)

Process	Functions	Advanced Capability
Supply Chain Management End-to-End Product/Service Delivery	• • Order processing Design, plan, buy, make, sell, deliver, collect	• • e-Business Full network connectivity
Procurement Sourcing Material/Service Acquisition	• • • • Supply base Enterprise leverage Strategic sourcing Key suppliers	• • • Auctions JIT scheduling Network collaboration
Logistics Transportation, Storage, Delivery	• • • Enterprise leverage Selective outsourcing Asset utilization	• • • Virtual systems Global tracking and delivery Consortium distribution
Demand Management Forecasting, Planning and Order Management	• • • • Sales forecasting Order processing SKU consolidation Replenishment	• • • • Consumption trigger Higher turns High forecast accuracy Low forecast bias
Capacity Planning and Inventory Management	• • • • Supply capability Core competence Cycle time consistency Inventory, buffers	• • • Flexible response Lower variability Constraint elimination
Sales and Operations Planning	• • • Matching supply and demand planning Performance review Strategic use of resources	• • • Value chain planning Synchronized material flow High service/fill rates
Advance Scheduling and Planning	• • • Manage volatility Available to promise Distribution planning	• • • Balanced costs Lead time reduction Integrated work processing
Supplier Relationship Management	• • • Key supply arrangements Standards, protocols e-Procurement • Partnering in trust	• • • Network visibility Revenue development VMI • Joint strategies/planning
Customer Relationship Management	• • • • Customer segmentation Customer analytics Data sharing Joint business goals	• • • Network market knowledge Joint technology adoption Database marketing
Collaborative Design and Manufacturing	• • • Selective supplier assistance Product lifecycle management Time to market	• • • • End consumer satisfaction SRM/CRM convergence Collaborative product design Higher success rate
Collaborative Planning, Forecasting and Replenishment	• • • Channel partner cooperation Technology application Material/product visibility	• • • • Automatic replenishment Joint sales forecasting Action matches with variance Network management

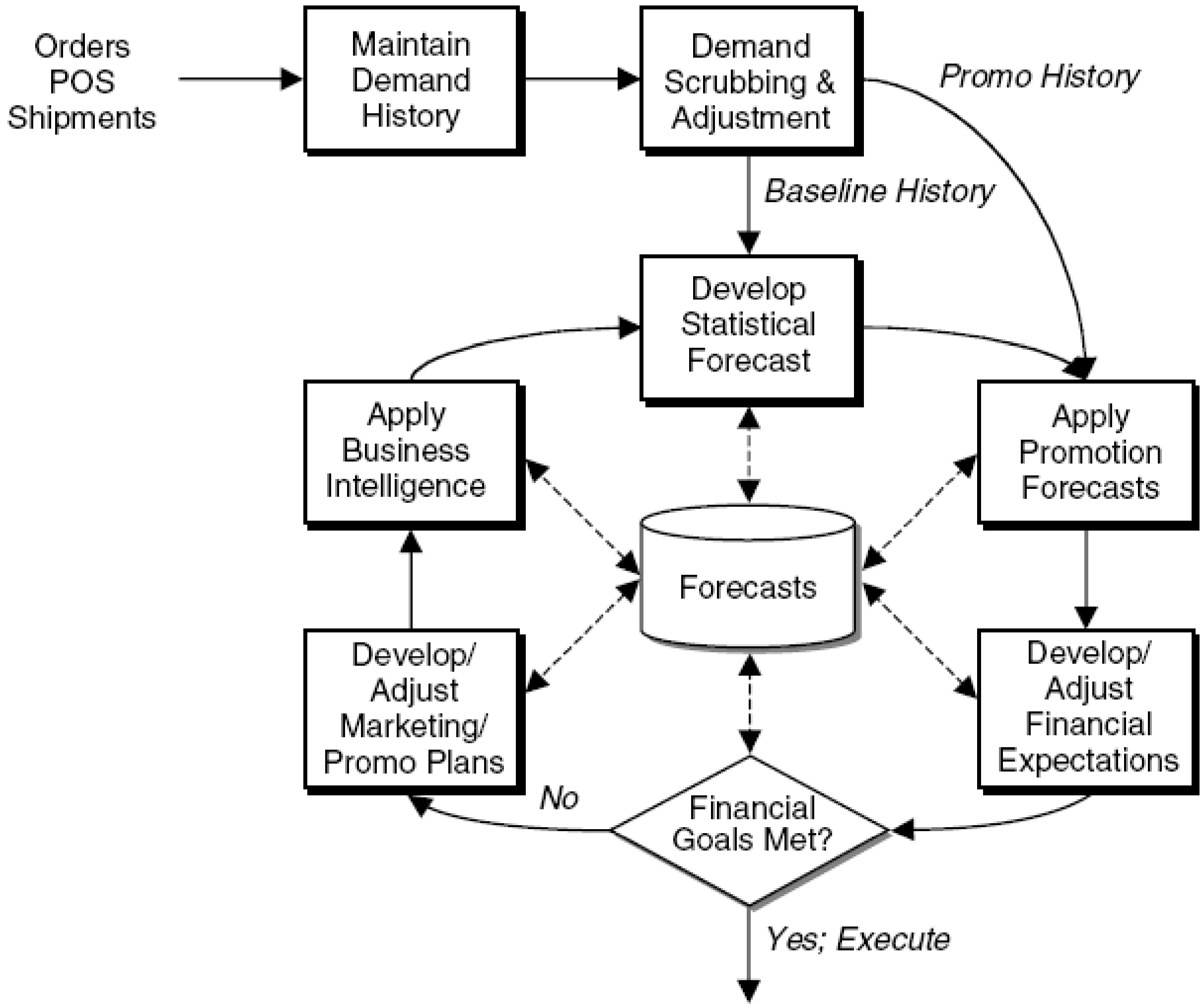

Consumer Relationship Marketing
Demand Forecasting
• Enterprise Supply Chain Planning
Trade Sales and Marketing (Decision Support Workbench)
Enterprise Data Warehouse
Global Data Warehouse Architecture
Supply Chain Management
• Manufacturing Systems Standardization Global Purchasing System
• Enterprise Supply Chain Planning
Retail Operations
Information Infrastructure MIS Capacity Improvement
• MIS Capability Improvement
• Masterfiles Reengineering
• Network Deployment
• e-Mail Infrastructure


High
Economic Value
Low
"Home Runs"
Demand Forecasting
Operations
Supply Chain Mgt
Secondary Priorities
Consumer Relat. Mgt
Trade Sales & Marketing
Enterprise Data Whse
"Bite the Bullet"
Don't Bother
Challenge the Need
Infrastructure
Low
Strategic Imperative/ Competitiveness
High

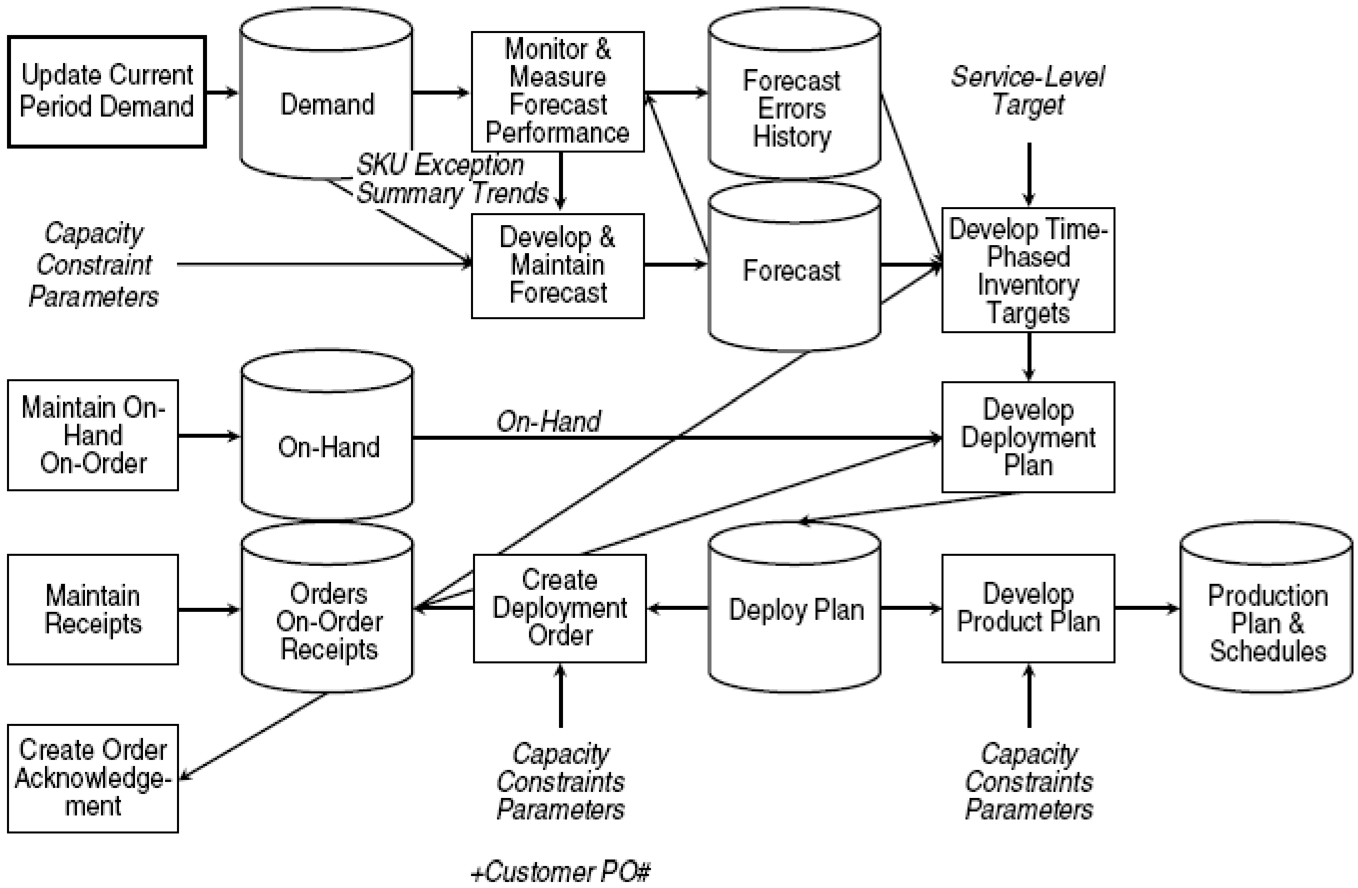
LINKING FORECAST TO OPERATIONS



Forecast , a circular process



LINKAGE FORECASTING TO OPERATIONS



ENTERPRISE DEMAND MANAGEMENT

Capacity to Meet Demand

Driver

Key Suppliers	Buy-Side (SRM)	Internal Operations	Sell-Side (CRM)	Key Customers
• Available-to-supply • Constraints variability • Inventory management • Order status, tracking • Engineering, manufacturing changes • Design-to-buy • Design collaboration	• Purchase order • Supply chain requirements • Inbound logistics • Replenish-ment release • Supply planning • Forecast adjustment • Market response	• Bills of material • Sales & operations planning • Advance planning & scheduling • Manufacturing • RM, WIP, finished goods • Inventories • Warehouse space	• Available-to-promise • Adjusted forecasts • Shipping schedules • Warehouse/ DC releases • Outbound logistics • Fulfillment • Return handling • Distribution deployment (promotions)	• Demand forecasts • VMI requirements • Replenishment information • Store deployment • Consumption visibility • Purchase orders

Consumer Demands (Actual Needs)

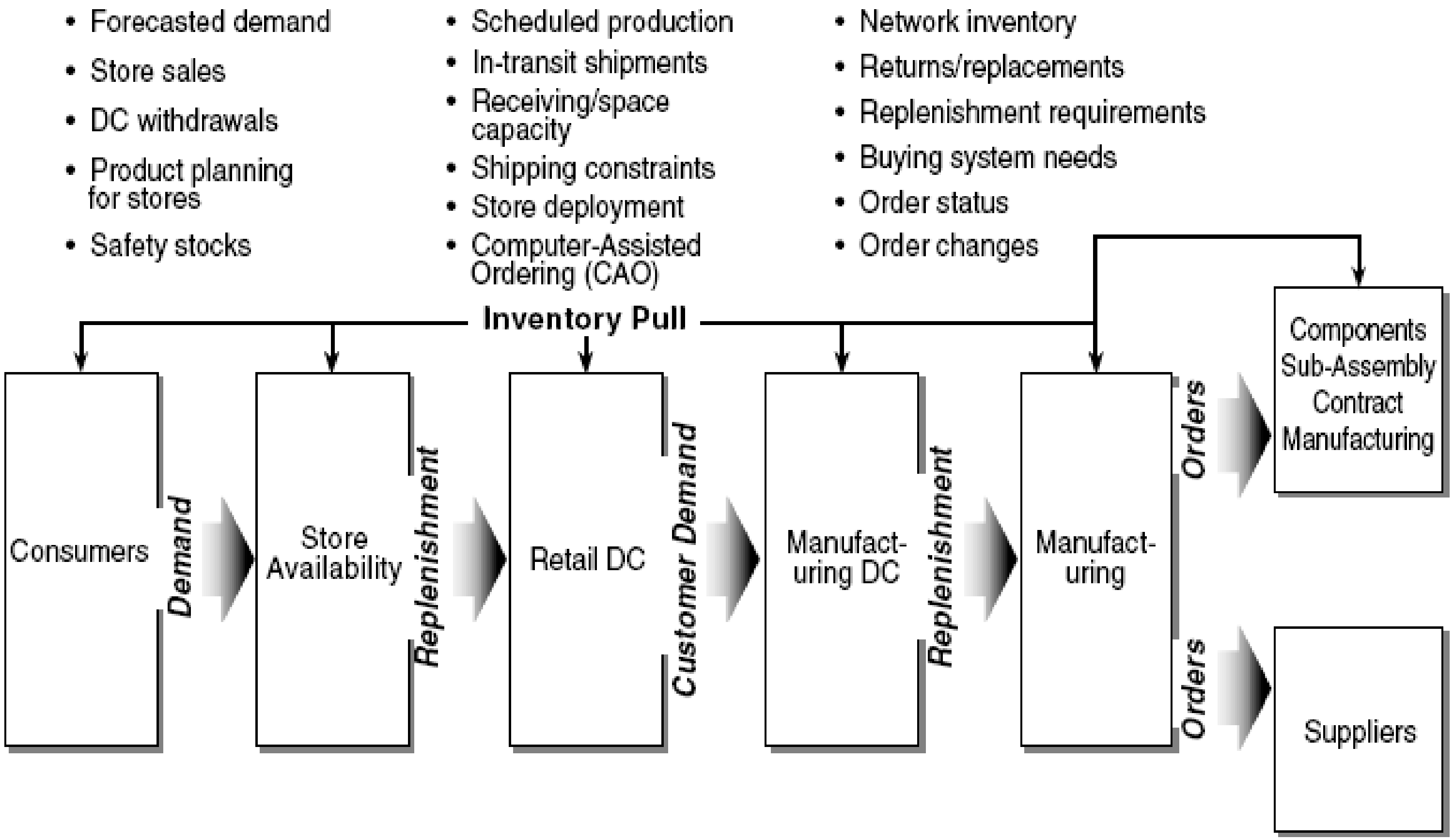
← *Online Visibility* →

← *Constraint Identification and Control* →

Physical Flow of Goods & Services →

Supply Chain Management

Matching Demand & Capacity



•An effective supply chain effort moves from the early savings made in sourcing and logistics to improving inventory management, planning, and scheduling.

•The accuracy of the sales forecast, and the proper handling or mishandling of market data and information on actual consumption, dramatically affect these process steps.

•While most firms suffer from low levels of forecast accuracy and often fail to take advantage of what is known about demand and supply, improvements can be made.

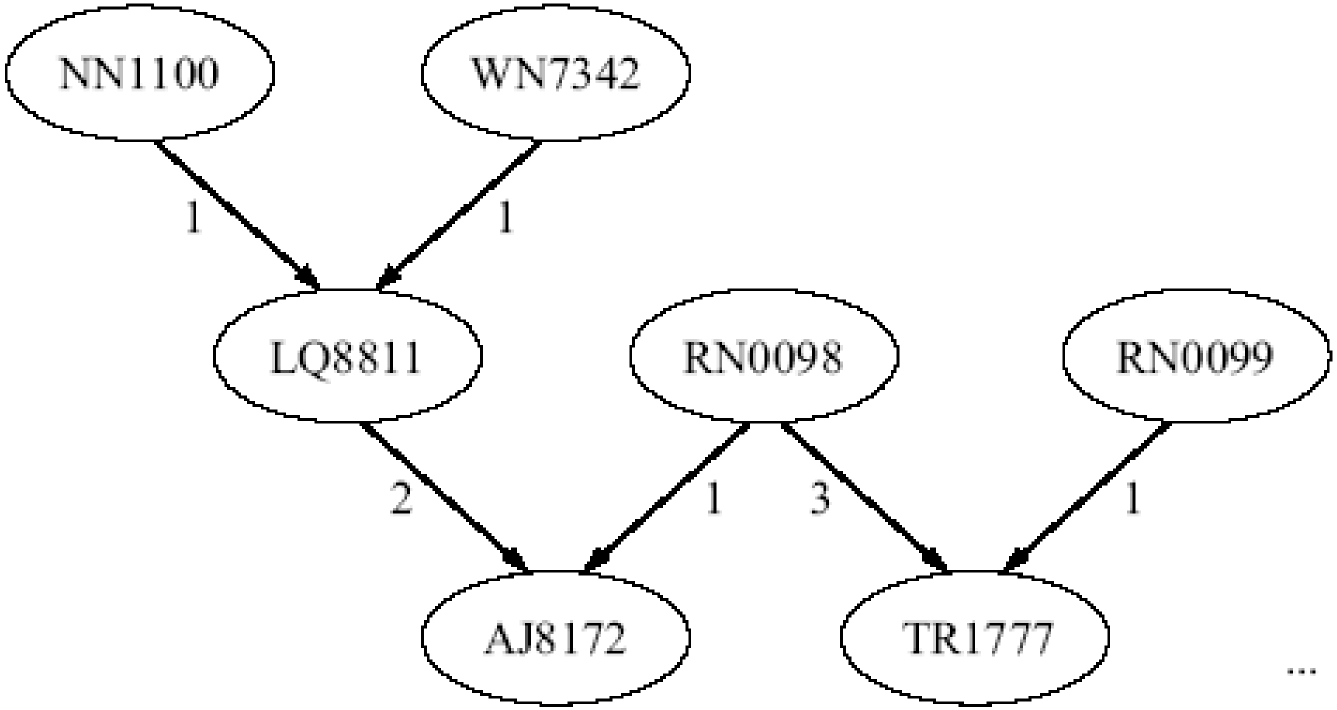
By applying the models described, forecast accuracy can be increased to 70 or 80%, and beyond for advanced firms. With better incoming data, all of the subsequent process steps improve. Then the firm can move to balance demand management with capacity capabilities by taking advantage of shared market and production information with selected business partners.

maximize profit

subject to:

production of each product	not less than	strategic lower limits,
and total production	not greater than	capacity.

BOM



AJ8172	Day 1	2	3	4	5	6	7	8
Demand	20	30	10	20	30	20	30	40
Inventory Plan (90)	70	40	30	10	80	60	30	90
Planned Receipts					100			100
Planned Releases			100			100		

LQ8811	Day 1	2	3	4	5	6	7	8
Demand			200			200		
Inventory Plan (300)	300	300	100	100	100	300	300	300
Planned Receipts						400		
Planned Releases			400					

RN0098	Day 1	2	3	4	5	6	7	8
Demand			100			100		
Inventory Plan (100)	100	100	0	0	0	0	0	0
Planned Receipts						100		
Planned Releases		100						

P	Number of SKUs
T	Number of time buckets (i.e., the planning horizon)
$LT(i)$	Lead time for SKU i
$R(i, j)$	Number of i's needed to make one j
$D(i, t)$	External demand for i in period t
$I(i, 0)$	Beginning inventory of SKU i
$LS(i)$	Minimum lot size for SKU i
M	A large number

SKU : stock keeping unit , can be sold

The following constraints must hold for all $i = 1, \ldots, P$ and $t = 1, \ldots, T$.

- Demand and materials requirement:

$$\sum_{\tau=1}^{t-LT(i)} x_{i,\tau} + I(i,0) - \sum_{\tau=1}^{t} \left(D(i,\tau) + \sum_{j=1}^{P} R(i,j) x_{j,\tau} \right) \geq 0$$

- Lot size requirement:

$$x_{i,t} \geq \delta_{i,t} LS(i)$$

- Modeling constraint for production indicator:

$$\delta_{i,t} \geq \frac{x_{i,t}}{M}$$

- Integer constraint for production indicator:

$$\delta_{i,t} \in \{0, 1\}$$

- Non-negative production:

$$x_{i,t} \geq 0$$

Minimize:

$$\sum_{i=1}^{P}\sum_{t=1}^{T}(T-t)x_{i,t} \qquad \textbf{(mrp)}$$

subject to:

$$\sum_{\tau=1}^{t-LT(i)} x_{i,\tau} + I(i,0) - \sum_{\tau=1}^{t}\left(D(i,\tau) + \sum_{j=1}^{P} R(i,j)x_{j,\tau}\right) \geq 0 \qquad i=1,\ldots,P,\ \ t=1,\ldots,T$$

$$x_{i,t} - \delta_{i,t}LS(i) \geq 0 \qquad i=1,\ldots,P,\ \ t=1,\ldots,T$$

$$\delta_{i,t} - \frac{x_{i,t}}{M} \geq 0 \qquad i=1,\ldots,P,\ \ t=1,\ldots,T$$

$$\delta_{i,t} \in \{0,1\} \qquad i=1,\ldots,P,\ \ t=1,\ldots,T$$

$$x_{i,t} \geq 0 \qquad i=1,\ldots,P,\ \ t=1,\ldots,T$$

Classic versions of MRP, as well as our optimization formulation, are intended only for certain types of bills of material.

Bills of material where multiple SKUs are combined to make a new SKU work well. This is the case with many things such as computers and cars.

Products where one item is used to produce multiple items are referred to as *divergent* BOMs. For divergent portions of the BOM, the entries in $R(i, j)$ will be fractional.

Of course, no production planning model can be perfect, but there are a number of well-known and very severe problems with MRP as we have described it. Perhaps the three most serious problems are :

•the actual time to complete an order is usually a function of congestion rather than of the SKU,

•lot sizing can cause *nervousness,*

• *there are no capacity constraints.*

It turns out that these problems are related. The lack of capacity constraints results in a need for lot sizing and exacerbates the variable lead time problem considerably.

The trouble with lead times is that they are given as static data. However, the time from issuance of an order to completion depends mainly on what work has to be done before the order "gets to the front of the line" of orders that await processing. Lead times are often weeks when the actual production time is hours.

One reason that lead times have to be much longer than production times is to account for machine failures. But even if the capacity is not over utilized and if the production resources are reliable, lead times can be variable due to waiting lines that form in front of bottleneck resources. This issue can be important but it is difficult to deal with, so it must be deferred to a later research

A major part of the reason that lead times must be so long is to guard against periods when the resources are overbooked. This can be mitigated considerably by the use of capacity constraints, which are not included in MRP

Nervousness is a phenomenon where small changes in demand result in large changes in production plans due to lot sizing rules.

If the company received an order for ten more AJ8172's in period four, it would cause production to be shifted earlier and production for the entire lot of 400 LQ8811's would be shifted one period earlier as well.

The dynamics of nervousness makes it demoralizing for production workers and as a result they often ignore the production plans produced by mrp systems.

First the production plan is released to the floor, then a modest size order causes large changes in the schedule; meanwhile order cancellations can have a similar effect

One response to this problem is to produce a “frozen zone” for end items that forbids changes in the schedule for some number of near-term time buckets.

This seldom works. The reason is that customers do not care about mrp induced nervousness. They demand flexibility.

As a result, orders get changed whether the master production schedule reflects it or not. In the worst case (a common case, unfortunately) expeditors manipulate inventories and production schedules to respond to customer needs

A major reason to use large lot sizes, or lot sizing rules at all, is to ensure that not too much productive capacity is used to changeover from one SKU to another.

In reality, one cannot know how big the lot sizes need to be until the production schedule is complete.

For resources that do not happen to be capacity constrained in a time period, the addition of more changeovers will not adversely affect throughput, so smaller, more flexible lots can be used.

Conversely, for resources that are capacity constrained, a delicate tradeoff is needed between the use of small lots to provide flexibility in meeting customer needs and the use of large lots to maximize throughput.

Setting lot sizing rules *a priori* is hardly delicate

MRP II

Although we have introduced it as a planning tool, mrp is also often used as a scheduling tool as well. A severe problem is that there is no guarantee that there will be enough capacity to actually carry out the plan produced by mrp. In fact, for capacity constrained production systems, it is seldom possible to implement an mrp plan as a schedule.

This is debilitating when mrp is used as a scheduling tool, but is also bad for mrp as a planning tool because the absence of capacity considerations can make the plans so unrealistic that they are not useful.

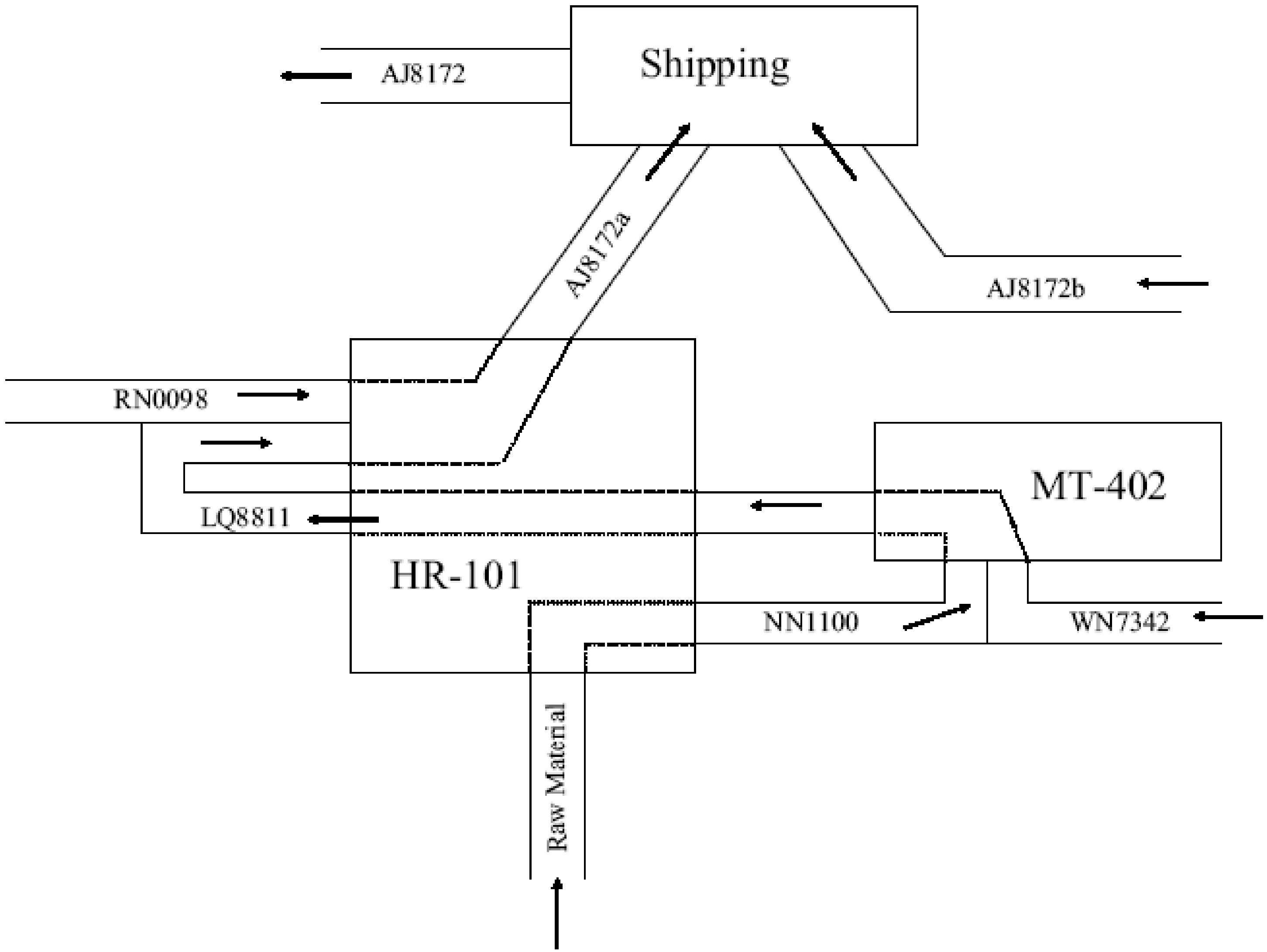
The data processing professionals who were developing and selling mrp software in its early years recognized this deficiency and MRP II was developed in response to it.

The database for mrp is extended to include routing and capacity information.

Each production resource is entered into the database along with its maximum production during a time bucket.

We will refer to the maximum production by a resource during a time bucket as its *capacity.* The list of resources used to produce a particular SKU is known as the *routing* for the SKU.

Routing


Shipping
AJ8172
AJ8172a
AJ8172b
RN0098
LQ8811
HR-101
MT-402
NN1100
WN7342
Raw Material

P	Number of SKUs
T	Number of time buckets
K	Number of resources
$I(i,0)$	Beginning inventory of SKU i
$LT(i)$	Lead time for SKU i
$R(i,j)$	Amount of SKU i needed to make one j
$D(i,t)$	External demand for SKU i in period t
$U(i,k)$	Fraction of resource k needed to make one unit of SKU i

- Demand and materials requirement for all times t and all SKUs i:

$$\sum_{\tau=1}^{t-LT(i)} x_{i,\tau} + I(i,0) - \sum_{\tau=1}^{t} \left[D(i,\tau) + \sum_{j=1}^{P} R(i,j) x_{j,\tau} \right] \geq 0$$

- Constrain capacity for some (or all) resources k and times t:

$$\sum_{i=1}^{P} U(i,k) x_{i,t} \leq 1$$

- Non-negative production for all SKUs i and times t:

$$x_{i,t} \geq 0$$

Minimize:

$$\sum_{i=1}^{P}\sum_{t=1}^{T}(T-t)x_{i,t} \qquad \textbf{(MRPII)}$$

subject to:

$$\sum_{\tau=1}^{t-LT(i)} x_{i,\tau} + I(i,0) - \sum_{\tau=1}^{t}\left(D(i,\tau)+\sum_{j=1}^{P}R(i,j)x_{j,\tau}\right) \geq 0 \qquad i=1,\dots,P,\ \ t=1,\dots,T$$

$$\sum_{i=1}^{P}U(i,k)x_{i,t} \leq 1 \qquad t=1,\dots,T,\ \ k=1,\dots,K$$

$$x_{i,t} \geq 0 \qquad i=1,\dots,P,\ \ t=1,\dots,T$$

$$x_{i,t}-\delta_{i,t}LS(i) \geq 0 \qquad t=1,\dots,T$$

$$\delta_{i,t}-\frac{x_{i,t}}{M} \geq 0 \qquad t=1,\dots,T$$

$$\delta_{i,t} \in \{0,1\} \qquad t=1,\dots,T$$

$S(i,k)$	Fraction of resource k used to changeover to SKU i
$W(i,j)$	Waste of SKU i to changeover to SKU j

- Demand and materials requirement for all times t and all SKUs i:

$$\sum_{\tau=1}^{t-LT(i)} x_{i,\tau} + I(i,0) - \sum_{\tau=1}^{t}\left[D(i,\tau) + \sum_{j=1}^{P}\left(R(i,j)x_{j,\tau} + W(i,j)\delta_{j,\tau}\right)\right] \geq 0$$

- Constrain capacity for all resources k and times t:

$$\sum_{i=1}^{P}\left(U(i,k)x_{i,t} + S(i,k)\delta_{i,t}\right) \leq 1$$