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Supply Chain Management

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اللجنة الأكاديمية لقسم الهندسة الصناعية

2024

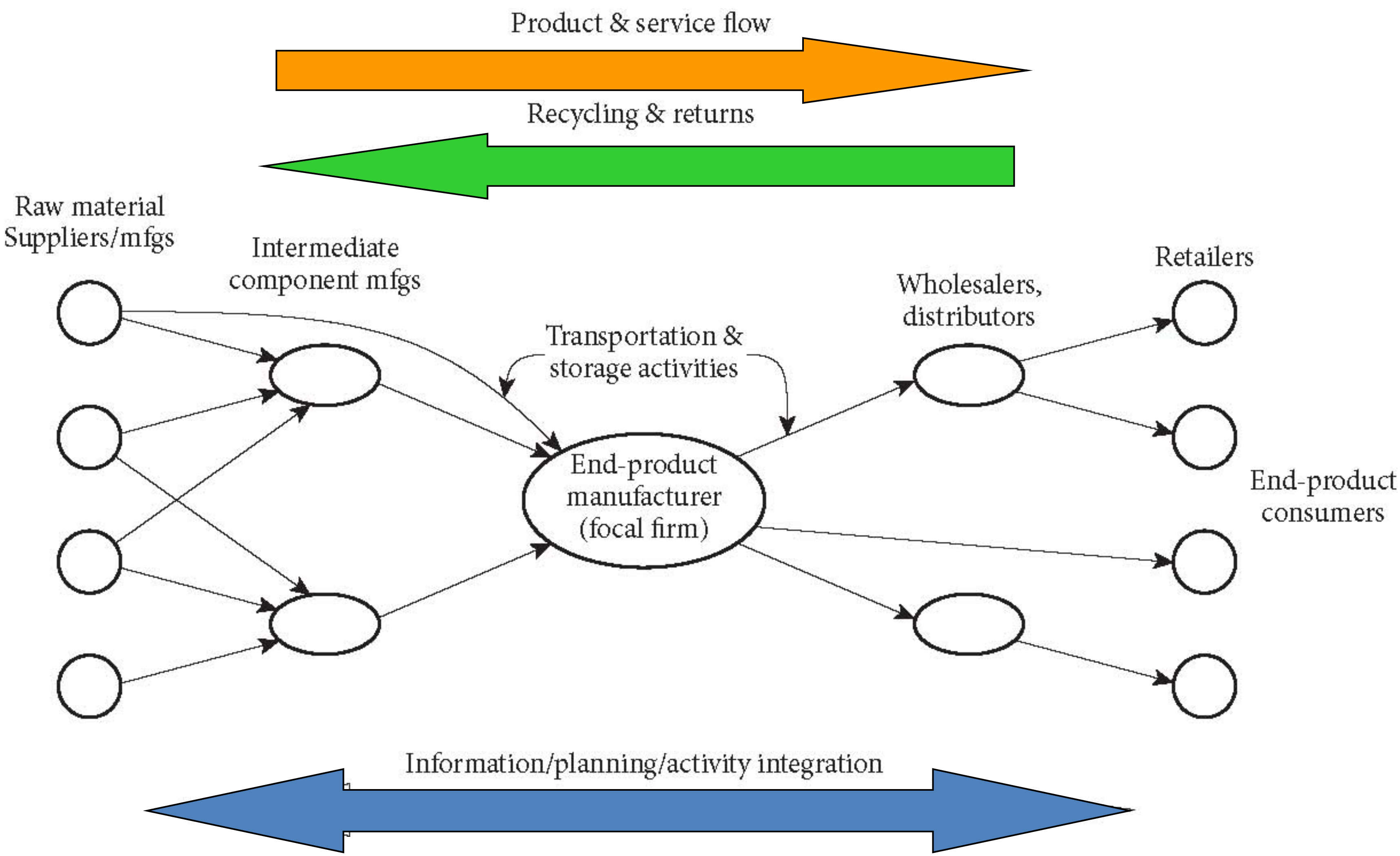
Supply chain management

Introduction

Supply & Demand

Operations & Supply Chains		Sales & Marketing	
Supply	**>**	**Demand**	**Wasteful** **Costly**
Supply	**<**	**Demand**	**Opportunity Loss** **Customer Dissatisfaction**
Supply	**=**	**Demand**	**Ideal**

What is a Supply Chain?



What is a Supply Chain?

A **supply chain** consists of the flow of products and services from:

- Raw materials manufacturers
- Component and intermediate manufacturers
- Final product manufacturers
- Wholesalers and distributors and
- Retailers

Connected by transportation and storage activities, and **Integrated** through information, planning, and integration activities

Many large firms are moving away from in-house **Vertically Integrated** structures to Supply Chain Management

What is supply chain management?

- The *supply chain* is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer
- *Supply chain management* (SCM) is the management across and within a network of upstream and downstream organizations of both relationships and flows of material, information and resources
  - The purposes of SCM are to create value, enhance efficiency, and satisfy customers

What is logistics?

- Logistics involves getting
  - the right product,
  - in the right way,
  - in the right quantity and right quality,
  - in the right place at the right time,
  - for the right customer at the right cost
- Its not just ‘trucks and sheds’

Key flows in SCM

- Physical flows of materials
- Flows of information that inform the supply chain
- Resources (especially finance, but also others such as people and equipment) which help the supply chain to operate effectively
  - Furthermore, not all resources in the supply chain are tangible, for example good quality inter-company relationships are often cited as a highly important ingredient of effective supply chains

Distinguishing logistics and SCM

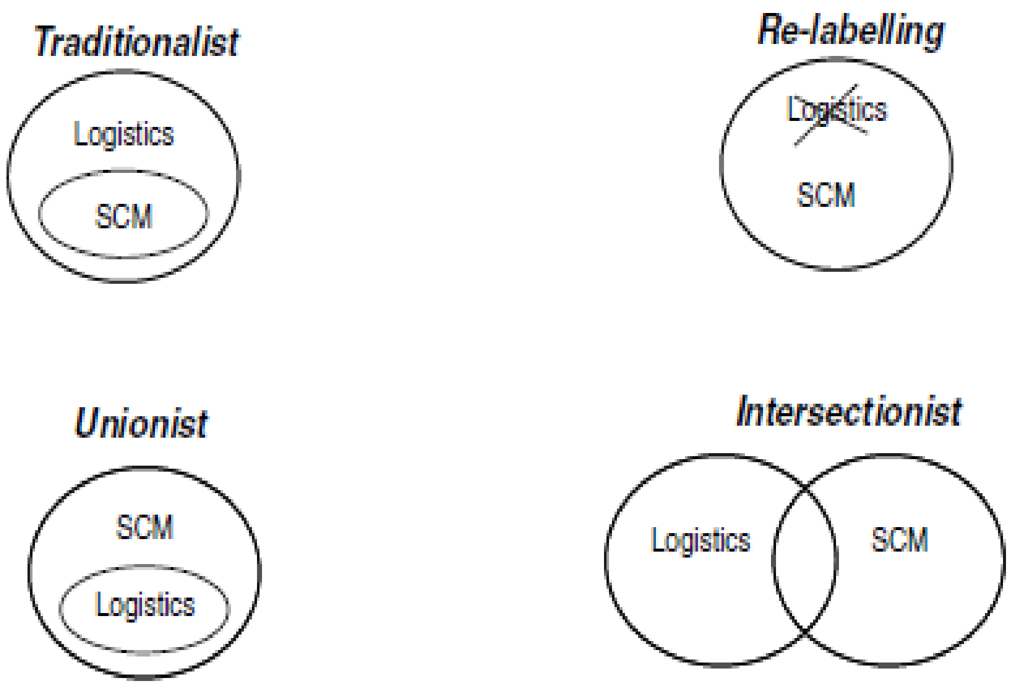


Figure 1.2 Four perspectives on logistics versus supply chain management (Source: Larson & Halldorsson, 2004)[11]

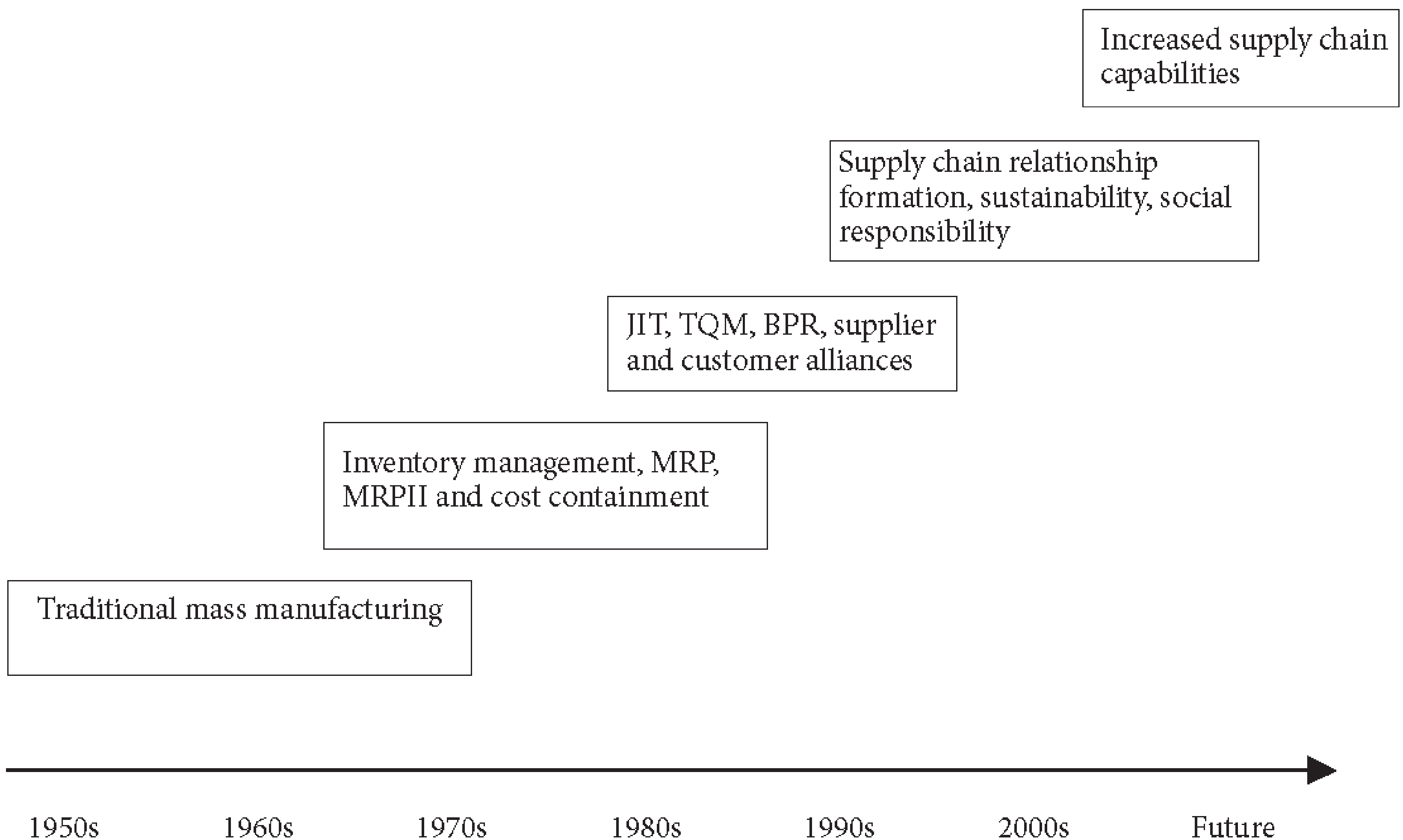
What is Supply Chain Management?

(continued)

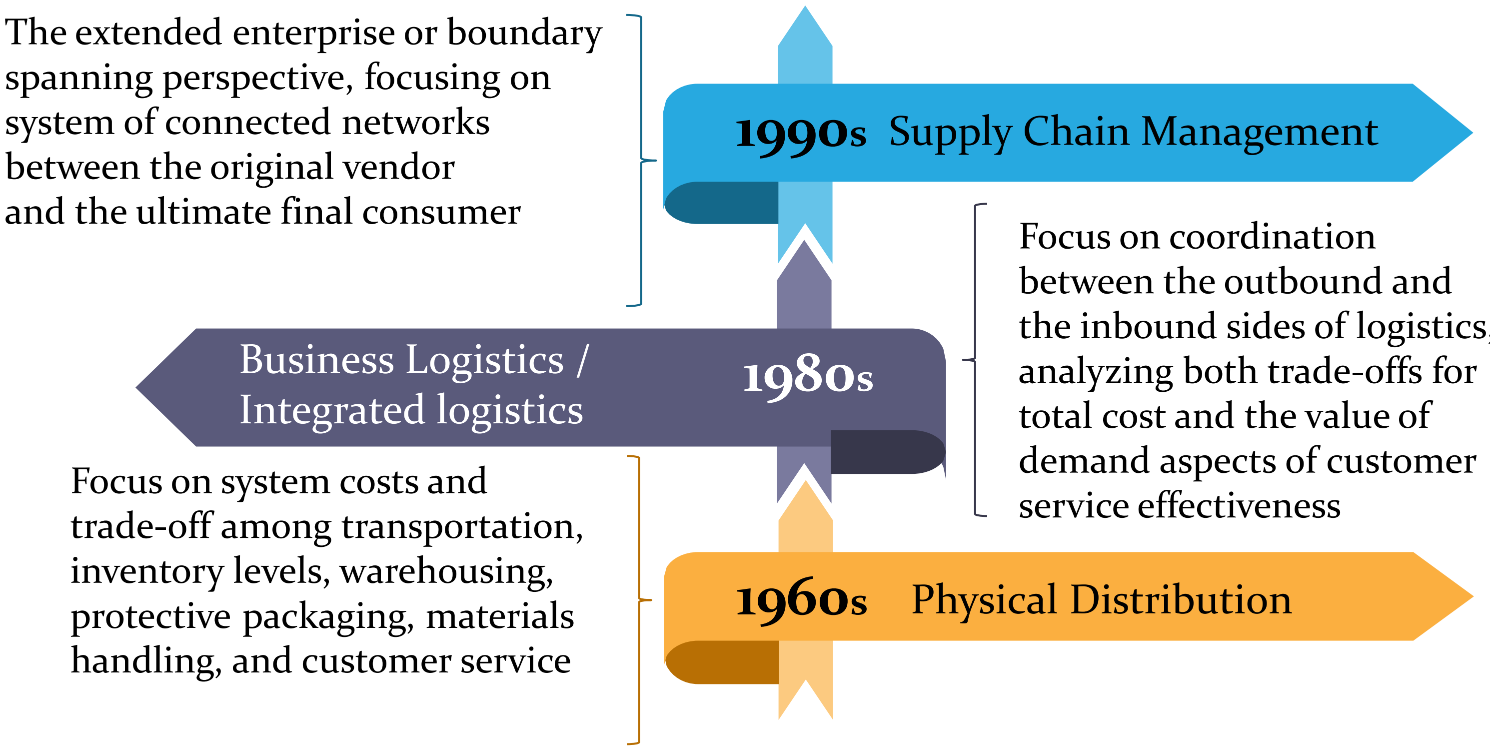
- ***Old paradigm*** - Firm gained synergy as a vertically integrated firm encompassing the ownership and coordination of several supply chain activities. Organizational cultures emphasized short-term, company focused performance.

- ***New paradigm*** - Firm in a supply chain focuses activities in its area of specialization and enters into voluntary and trust-based relationships with supplier and customer firms.
  – All participants in the supply chain benefit.
  – Boundaries are dynamic and extend from "the firm's suppliers' suppliers to its customers' customers (i.e., second tier suppliers and customers)."
  – Supply chains also include reverse logistics activities to handle returned products, warranty repairs, and recycling.

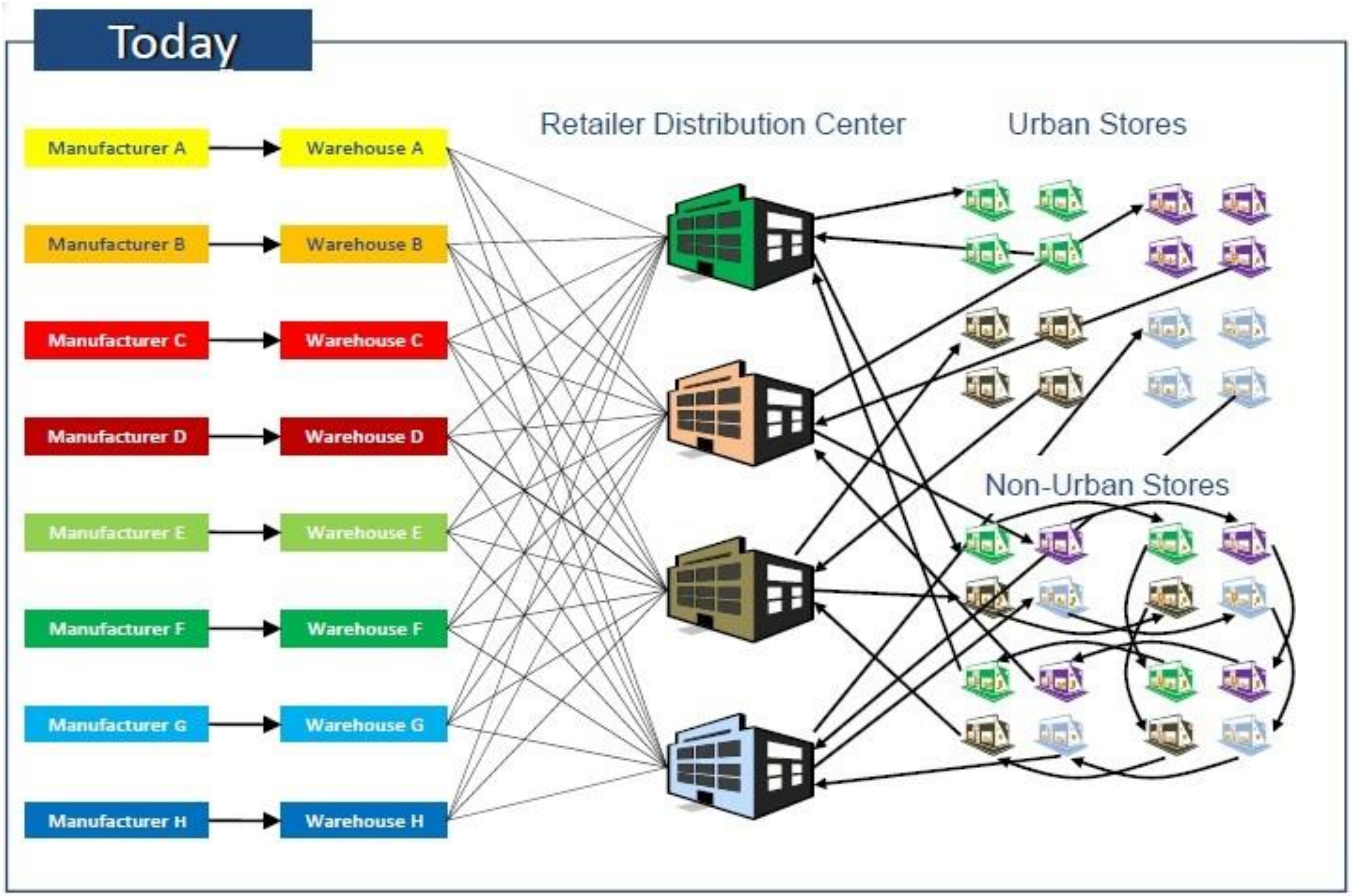
Origins of Supply Chain Management *(continued)*



Development of Supply Chain Concept



What is a Supply Network?



Logistics: A Better Definition

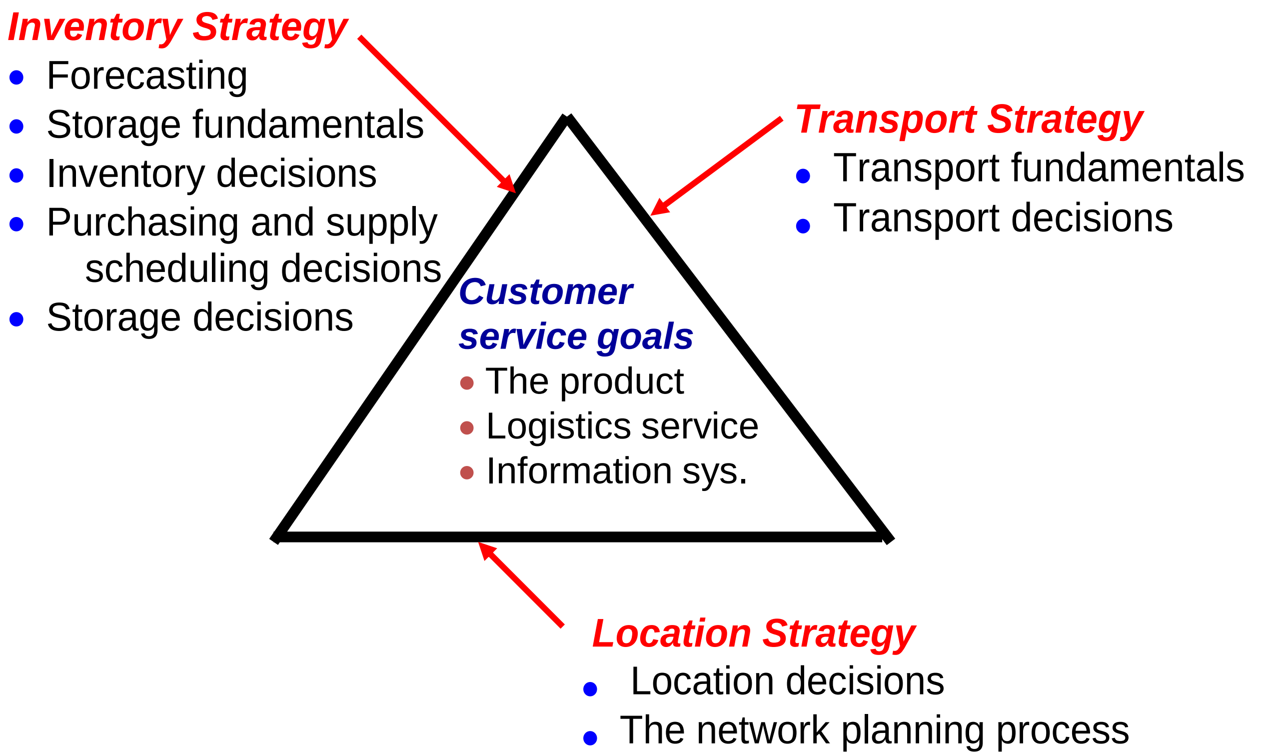
"Logistics is the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organisation and its marketing channels in such a way that current and future profitability are maximised through the cost-effective fulfilment of orders."

Source: Christopher, M. (2011), *Logistics & Supply Chain Management*, Fourth Edition, Pearson.

Decision-Making Areas in Logistics

Decision area	*Strategic*	*Tactical*	*Operational*
Transportation	Mode selection	Seasonal equip-ment leasing	Dispatching
Inventories	Location, Control policies	Safety stock levels	Order filling
Order processing	Order entry, transmittal, and processing system design		Processing orders, Filling back orders
Purchasing	Development of supplier-buyer relations	Contracting, Forward buying	Expediting
Warehousing	Handling equipment selection, Layout design	Space utilization	Order picking and restocking
Facility location	Number, size, and location of warehouses		

The Logistics Strategy Triangle (4 problem areas)



Robust SCM

Robust SCM strategy enables a firm to manage regular fluctuations in demand efficiently under normal circumstances regardless of the occurrence of a major disruption

Resilience

- Resilience – the ability of a system to return to its original (or desired) state after being disrupted

- Consideration of risk and resilience in SCM:
  - Encourages a whole system perspective
  - Explicitly accepts that disturbances happen
  - Implies adaptability to changing circumstances

Definition of reverse logistics

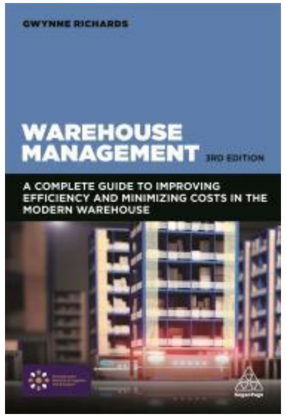
- Reverse logistics can be defined as:

“The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing or creating value or proper disposal”

A Service supply chain

- A service supply chain is the network of suppliers, service providers, consumers and other supporting units that performs the functions of transaction of resources required to produce services; transformation of these resources into supporting and core services; and the delivery of these services to customers.

Storage and Warehousing Techniques



Warehouse Management, 3rd edition by Gwynne Richards
Published November 2017 (Kogan Page)

Introduction and Background

Section 1

Warehouse definition

"Warehouses are typically viewed as a temporary place to store inventory and as a buffer in supply chains.

They serve as static units matching product availability to consumer demand and as such have a primary aim which is to facilitate the movement of goods from suppliers to customers, meeting demand in a timely and cost effective manner".

Primarily a warehouse should be a trans-shipment area where all goods received are despatched as quickly, effectively and efficiently as possible.

Van den Berg (2012)

Whether they're old….

Or ultra-modern

they have the majority of processes in common

The Objectives of Warehousing

- The primary objective of warehousing is to maximize the effective use of the operational resources while satisfying customer requirements.
- Match product availability to customer demand
- Maximum customer satisfaction at Minimum cost
- Ensure visibility and accuracy of stock
- SIX BASIC PRINCIPLES
  - Accuracy, Cost Control, Cleanliness, Efficiency, Safety & Security

Warehouse trade-offs

- Speed
- Time
- Cost
- Cost
- Efficiency
- Volume purchases

V

Accuracy

Space

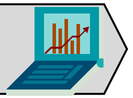
Service

Accuracy

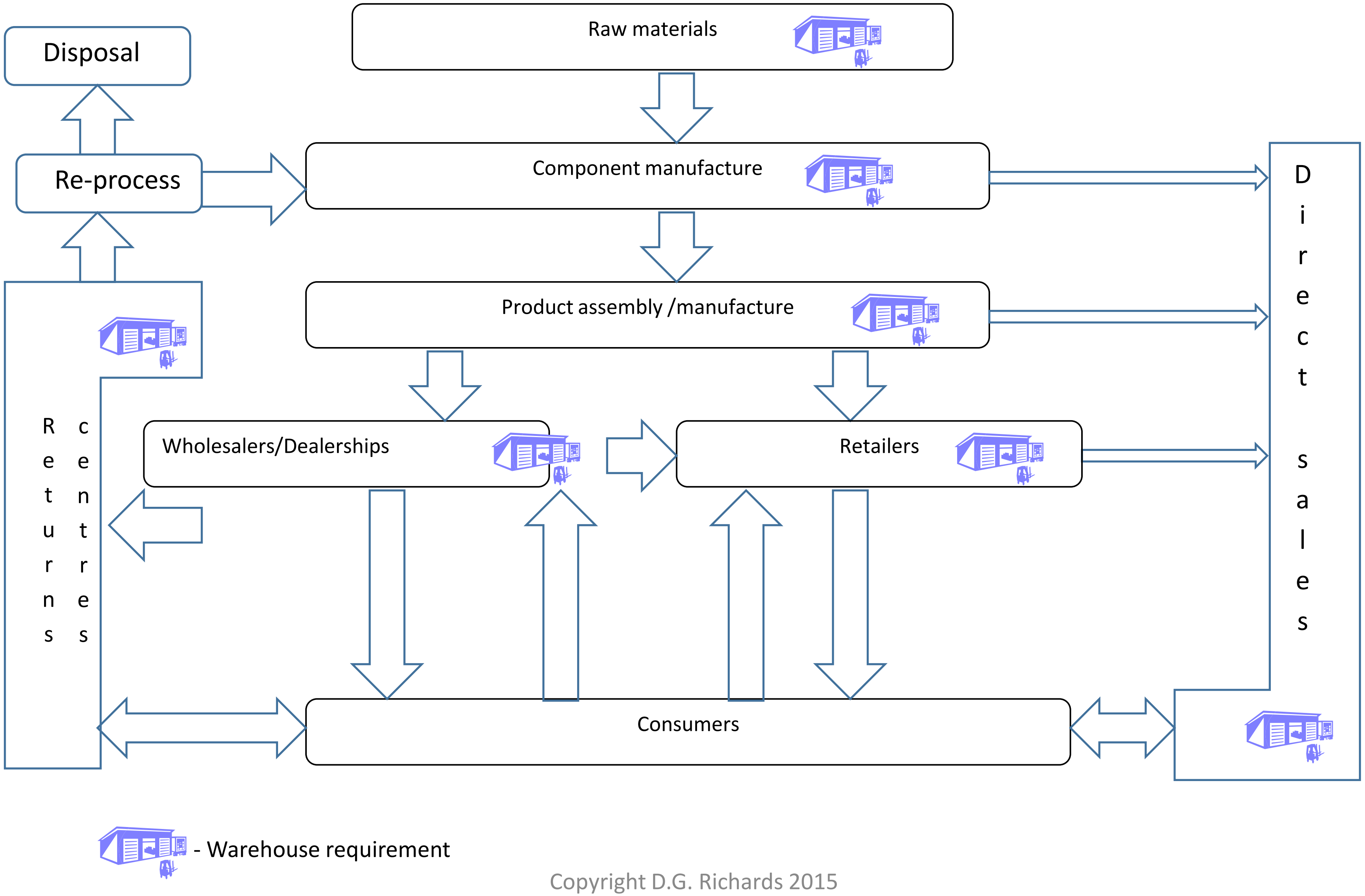
Responsiveness

Storage costs

Key Warehouse Challenges (Adapted from Dematic)

Challenge	Operational Requirements
Cost reduction 	Increase productivity, improve utilisation of space, staff and equipment
Achieve the Perfect Order 	Improve productivity, increase accuracy, improve handling and invest in systems
Shorter order lead times 	Improve processes and increase productivity
Sales via multiple channels and increase in smaller orders 	Improved picking strategies such as bulk picking and greater use of technology
Fluctuations in demand 	Flexible working hours and improved forecasting
Proliferation of SKU 	Improved use of equipment such as carousels, A Frames and flow racks
Labour cost and availability 	Staff retention through excellent working conditions, flexible hours, training and improved productivity
Increasing cost of energy and environmental challenges 	Manage energy more efficiently, better use of waste
Data accuracy and speed of transfer 	Introduce Warehouse management system and real time data transfer

Warehouses in the supply chain



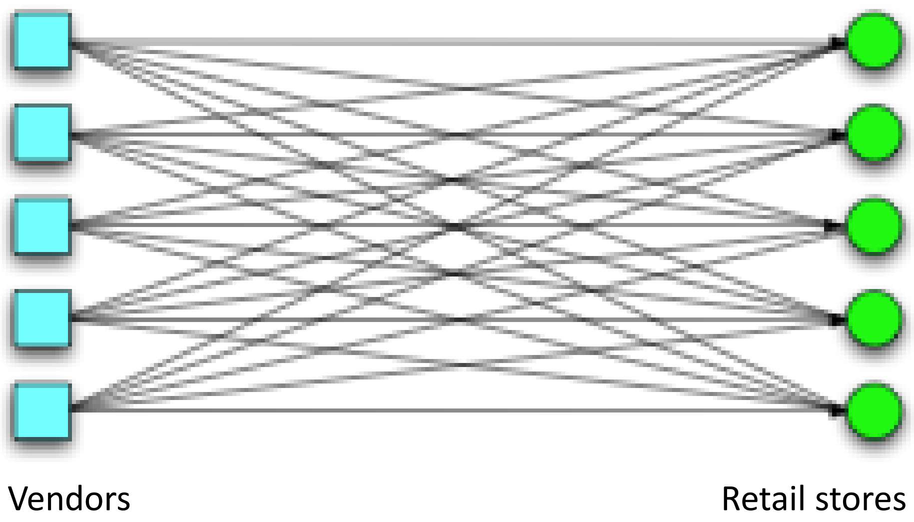
Role of the warehouse

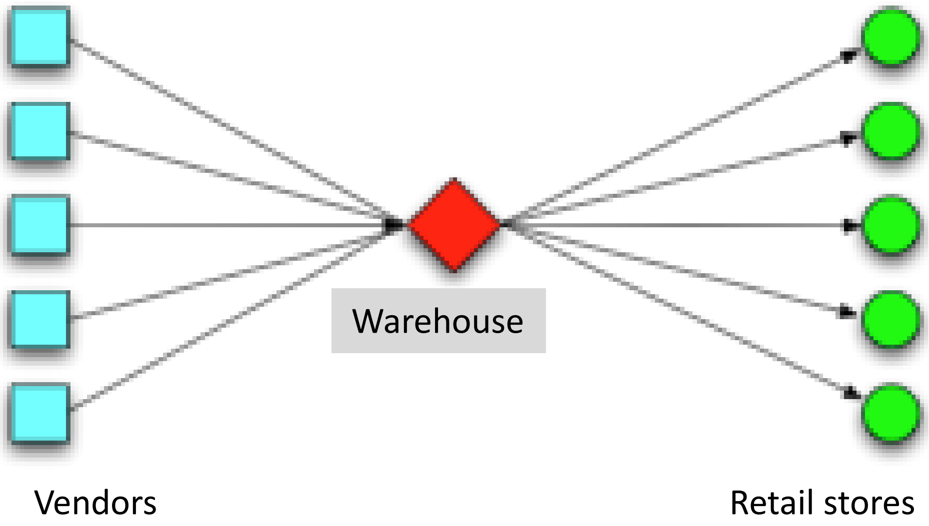
To facilitate getting the product to the customer:

- On time (OT)
- In Full (IF)
- To the right place
- In the right condition
- With the right paperwork
- At the right cost
- As environmentally friendly as possible

The need for retailer warehouses?

- To better match supply with customer demand
- To consolidate deliveries and reduce shipping costs
- To reduce store deliveries



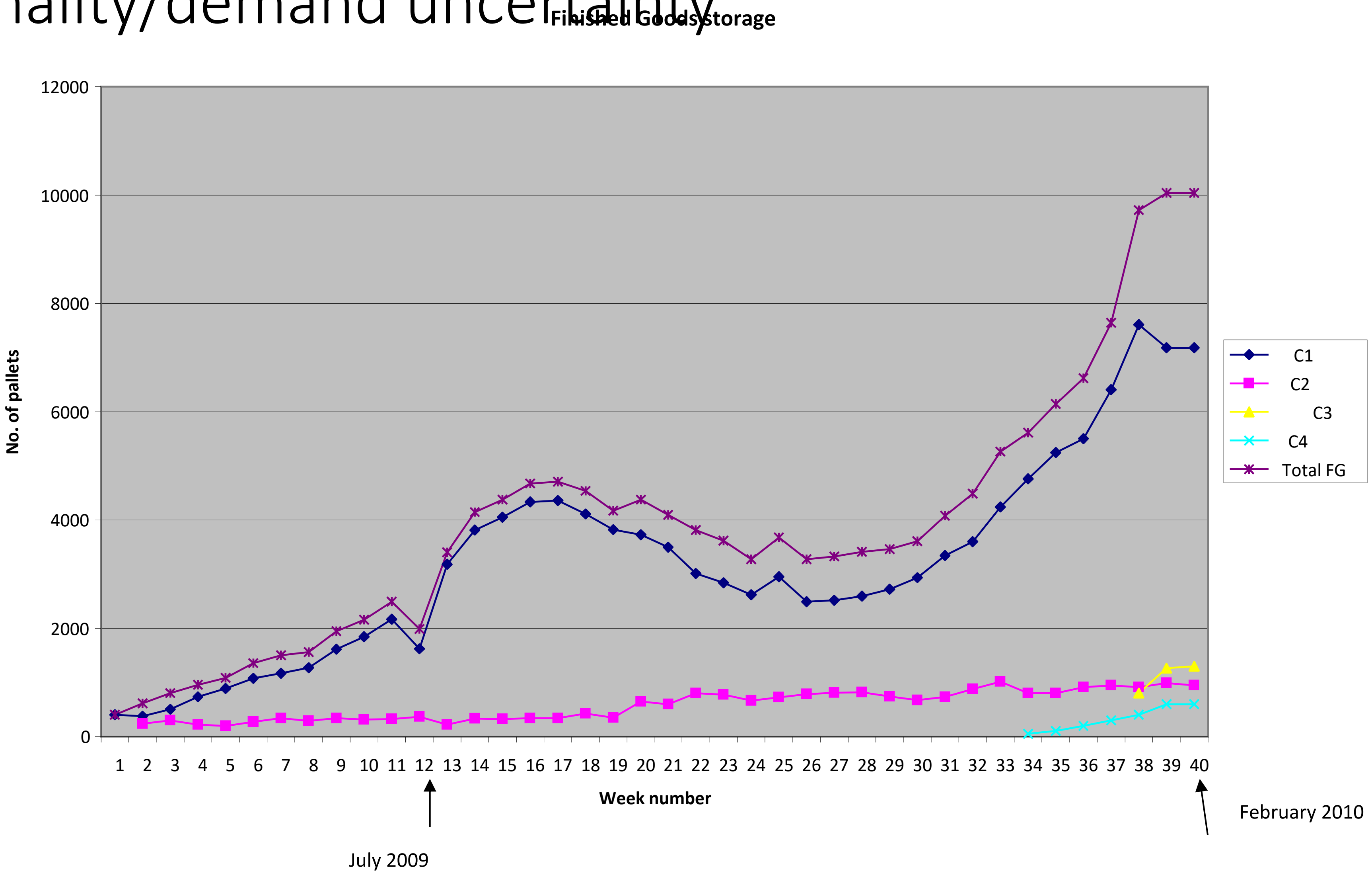


Why do we need to hold stock?

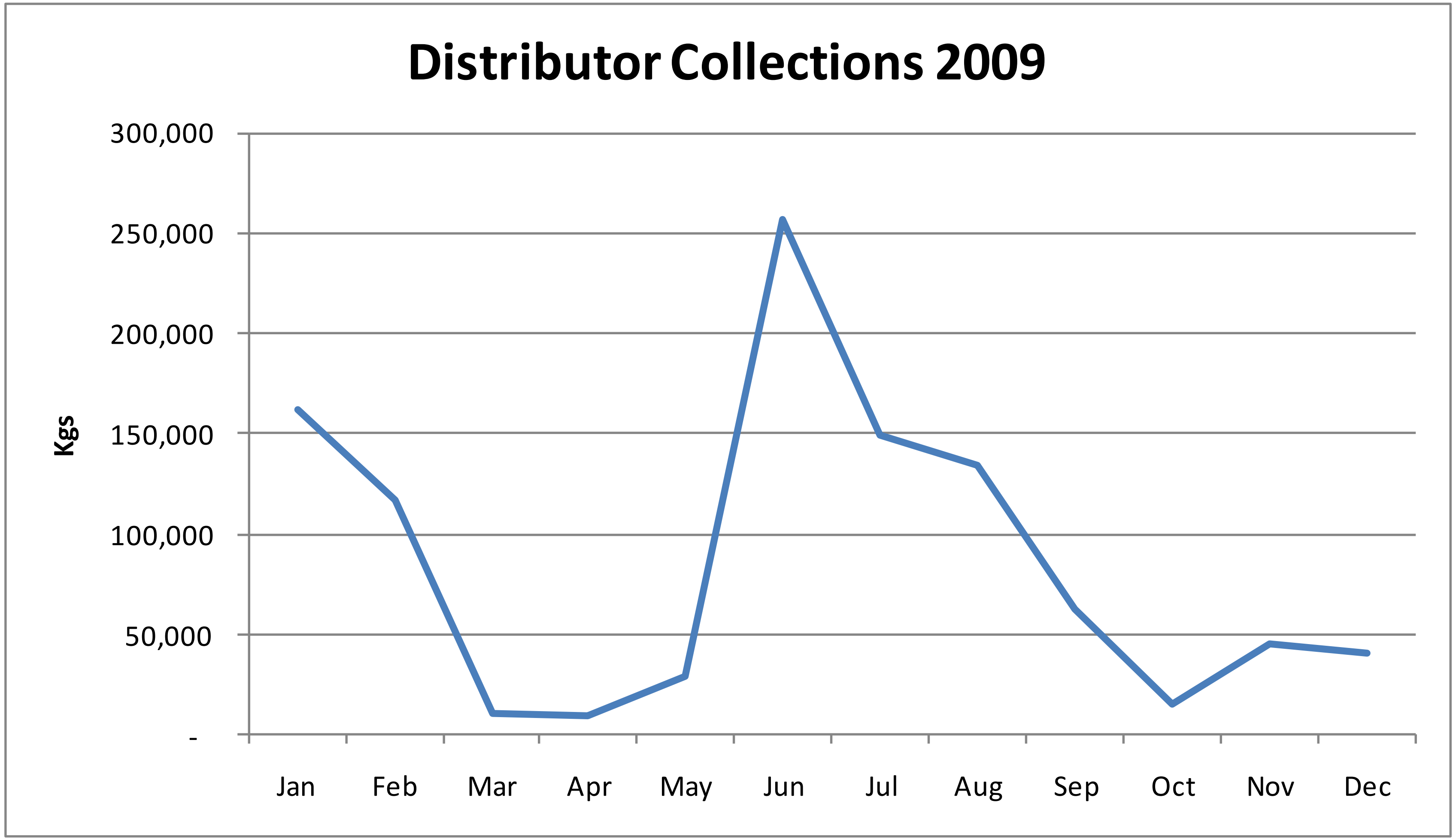
Why do we need to hold stock?

- Buffer in the supply chain or manufacturing process
- Satisfy demand – can be erratic
- Buy low sell high – precious metals, oil, coffee etc.
- Shortage or unreliability in supply
- Cope with peak demand - seasonality
- Maintenance parts
- Quality control cover
- Customer and supplier lead times
- Sub assembly
- Holding stock in numerous locations
- Ability to increase production runs
- Humanitarian storage
- Archive storage
- Smooth the flow of goods
- Packaging material
- Store returns
- Promotions and Product launch
- Cover for production shutdowns
- Lower unit cost if bought in large quantities and if transported in large quantities
- Production breakdown
- Ripening products, cheese, meats, whiskies
- Delay taxation payments

Seasonality/demand uncertainty



Seasonality/demand uncertainty

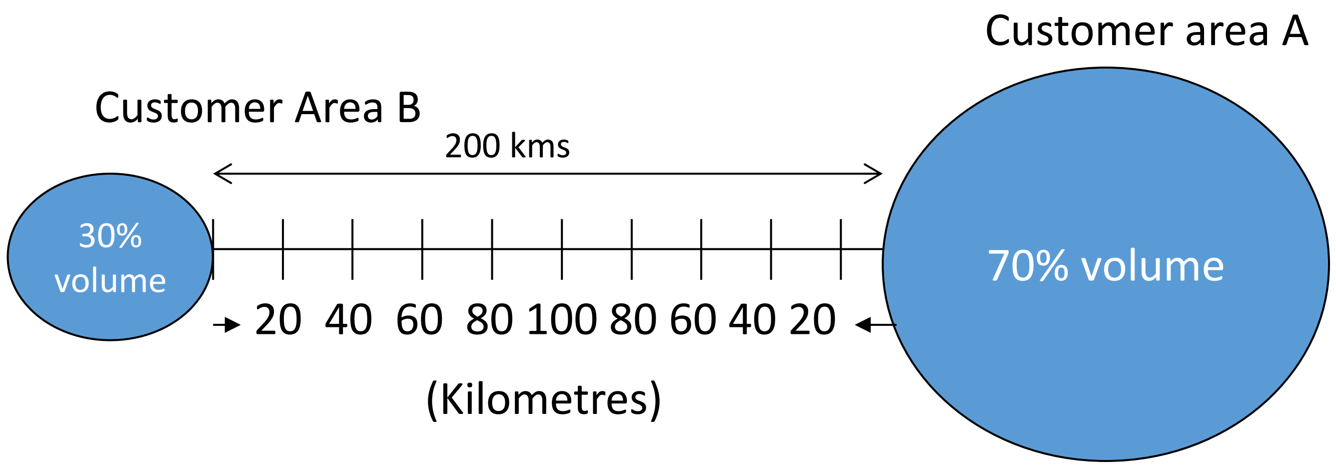


Warehouse Location

Section 2

Warehouse location

Exercise



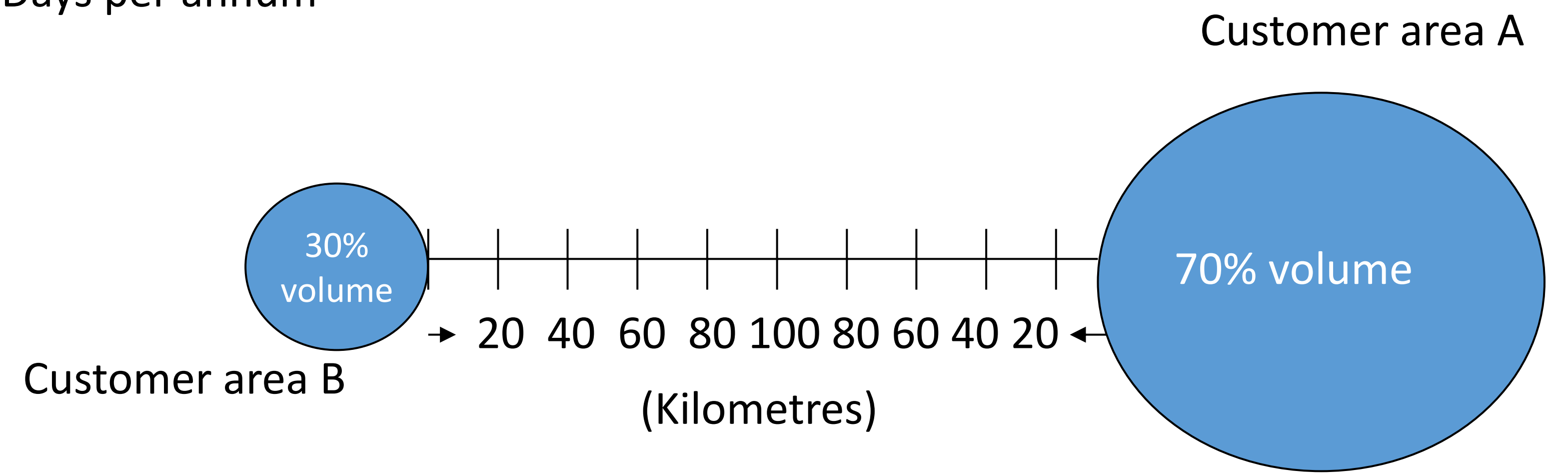
Where would you site a distribution centre to economically supply both customer areas?

Richards (2005)

Warehouse location

Exercise

Cost of transport = $5 per kilometre
70 loads per day into Customer area A
30 loads per day into Customer area B
200 Days per annum



Where would you site a distribution centre to economically supply both customer areas? What if it costs an additional $350,000 to operate a warehouse within 10 kms of customer area A? Minimum distance away is 1 km.

Richards (2005)

Calculations

Loads	Days	Kms	$ per km	Sub-Total	Additional cost (If applicable)	Total
70	200		$5			
30	200		$5			
TOTAL						
70	200		$5			
30	200		$5			
TOTAL						
70	200		$5			
30	200		$5			
TOTAL						
70	200		$5			
30	200		$5			
TOTAL						
70	200		$5			
30	200		$5			
TOTAL						

Answers

Loads	Days	Kms	$ per km	Total	SubTotal	Additional cost	Total
70	200	1	$5	$70,000			
30	200	199	$5	$5,970,000			
					$6,040,000	$350,000	$6,390,000
70	200	10	$5	$700000			
30	200	190	$5	$5700000			
					$6,400,000	$350,000	$6,750,000
70	200	11	$5	$770,000			
30	200	189	$5	$5,670,000			
					$6,440,000		$6,440,000
70	200	60	$5	$4,200,000			
30	200	140	$5	$4,200.000			
					$8,400,000		$8,400,000
70	200	100	$5	$7,000,000			
30	200	100	$5	$3,000,000			
					$10,000,000		$10,000,000

Richards (2005)

Exercise (continued)

- What other factors do you need to take into account when making this decision?

Factors affecting warehouse location

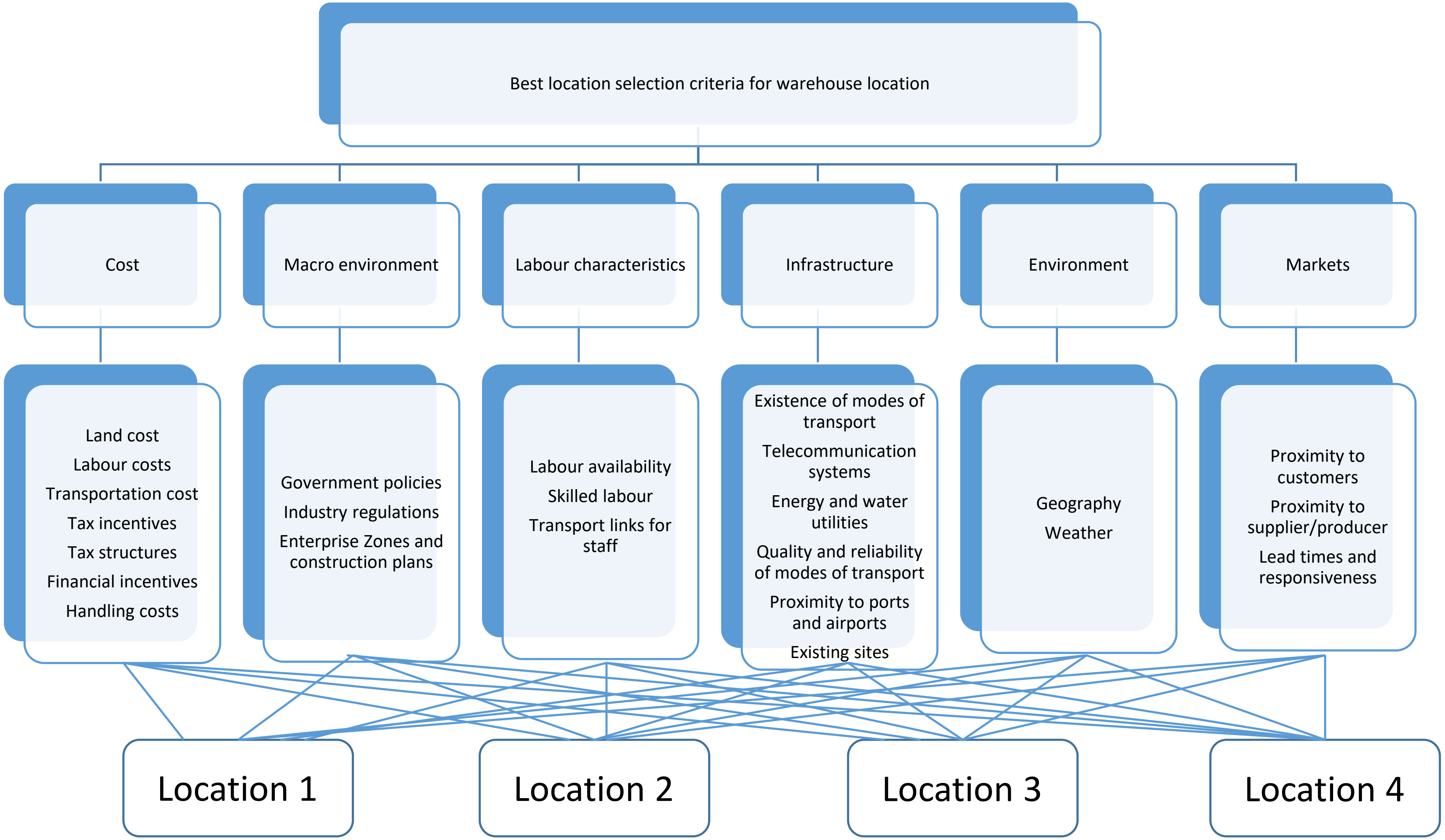
Of importance to Local Government Planners

- Utilisation of brown field sites
- Build in areas of high unemployment
- Appropriate mix of industry

Companies

- Access to transport networks e.g. parcel and pallet hubs
- Availability of trained labour
- Transport links for staff
- Availability of funding, grants etc
- Use of suitable existing buildings
- Availability of utilities including telecoms
- Availability of finance and resources
- Goods traffic flows
- Proximity to ports and airports
- Where are our suppliers and manufacturing points?
- No weather issues such as flooding

Warehouse location criteria



Adapted from T. Demirel et al./Expert Systems with Applications 37 (2010) 3943–3952

Port centric Logistics

"The provision of distribution and other value adding logistics services at a port."

Advantages:

- Faster unloading (emptying) of containers as long journeys from ports to DCs eliminated.
- Subsequent empty running between the DC and the port eliminated.
- Lower demurrage fees
- No need to worry about landside weight restrictions on imported containers allowing them to be filled to capacity.
- Faster repositioning of 'empties'.
- Reduced carbon footprint.

Example: Asda Walmart at Teesport

Location determination

Centre of Gravity

- Volume Centre of Gravity
  - Locates warehouse at the centre of supply & demand by minimizing distances to customers
- Cost Centre of Gravity
  - Locates warehouses at the centre of supply or demand by minimizing transportation costs

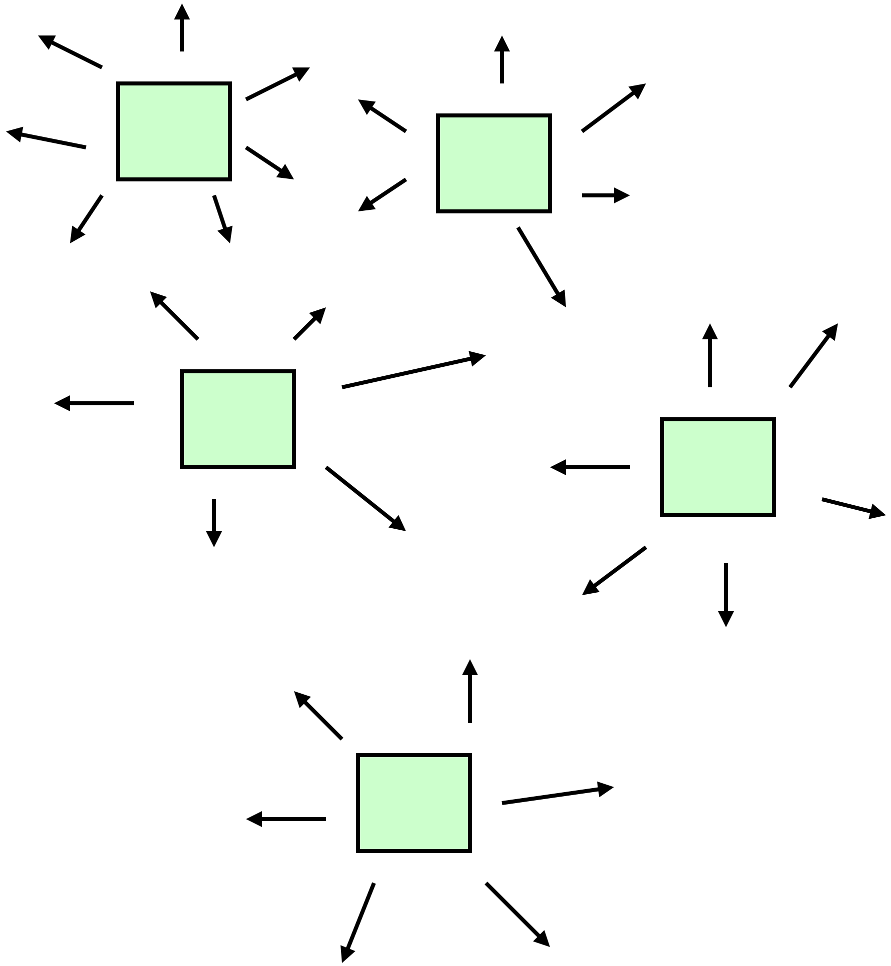
Global land and rent costs

USD/sq m/year			
Top 10	Rent	Outgoings	Total costs
London (Heathrow)	214.34	98.86	313.19
Hong Kong	222.96	48.31	271.27
Zurich	196.63	21.85	218.48
Singapore	174.19	40.51	214.70
Oslo	208.45	2.70	211.15
Moscow	157.00	48.00	205.00
St. Petersburg	144.00	41.00	185.00
South East England	122.48	57.74	180.22
São Paulo	152.13	26.04	178.17
Taipei	149.04	15.00	164.04
Bottom 15			
Philadelphia	42.73	32.34	75.07
Chicago	44.35	30.01	74.36
Shanghai	67.35	5.27	72.62
Budapest	51.45	20.58	72.03
Denver	38.10	33.25	71.35
Lyon	56.73	13.46	70.19
Houston	41.98	27.42	69.40
Brussels	60.69	7.59	68.27
Antwerp	59.37	8.13	67.50
Dallas	40.36	26.45	66.81
Marseille	54.09	12.14	66.23
Chengdu	59.60	2.98	62.58
Atlanta	42.19	17.00	59.19
Shenyang	54.69	3.66	58.35
Wuhan	42.44	4.39	46.83

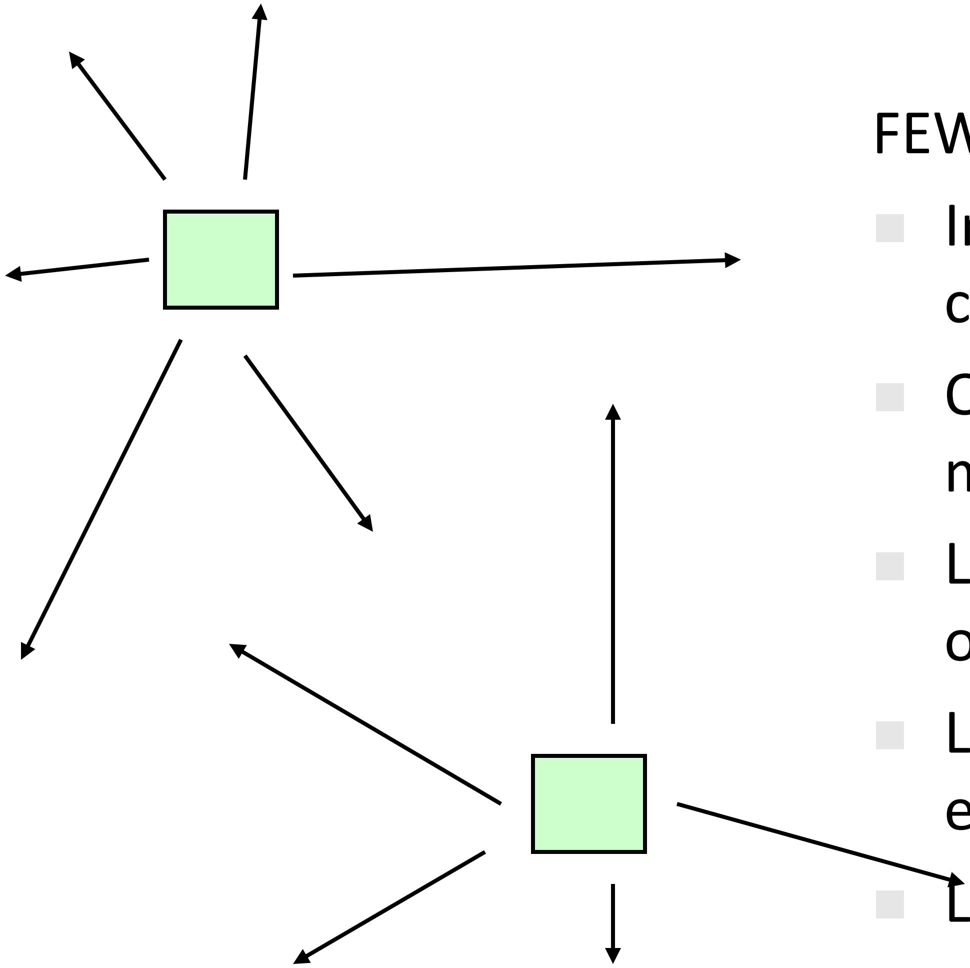
How many warehouses?

MANY WAREHOUSES

- Inbound transport is expensive (to supply warehouses)
- Outbound transport is cheaper (to deliver to customers)
- Closer to customers so quicker to react
- Cost of maintaining many warehouses is expensive
- Cost of keeping many buffer stocks is expensive



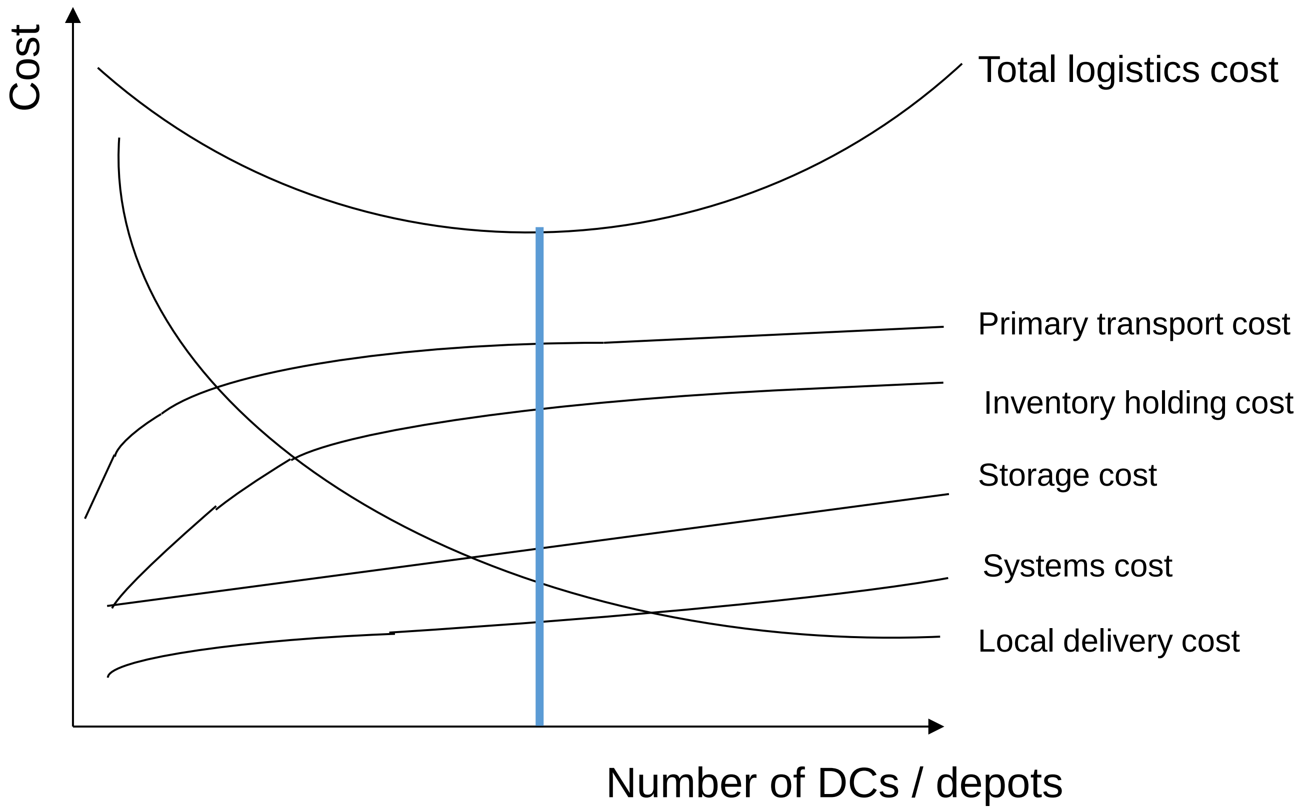
How many warehouses?



FEWER WAREHOUSES

- Inbound transport is cheaper
- Outbound transport is more expensive
- Less responsive to urgent orders
- Less cost to maintain & equip warehouses
- Less cost of buffer stock

Major Cost Relationships



Rushton, Croucher and Baker (2010)

Maister's Rule

Reducing the number of warehouses from y to x, reduces the total amount of safety stock in the system by:

$$1 - \frac{[\sqrt{x}\,]}{[\sqrt{y}\,]}$$

Multiply the result by 100 to find the percentage reduction

Exercise: Maister's rule

Use the data from the European manufacturer example to test Maister's rule:

- From 16 to 3 warehouses
- Original safety stock in the system was \$16M
- By how much will the stock be reduced?

$$1 - \frac{[\sqrt{x}]}{[\sqrt{y}]} =$$

Answer

Reducing from y to x

$y = 16 \qquad \sqrt{16} = 4$

$x = \ 3 \qquad \sqrt{3} = 1.732$

$$\% \text{ Reduction} = 1 - \frac{1.732}{4} = 56.7\%$$

56.7% of \$16M = \$9M

Maister's rule - grid

Original number of warehouses	Percentage extra stock or reduced stock for change in no. of warehouses							
	New number of warehouses							
	1	2	3	4	5	10	15	20
1	0%	41%	73%	100%	124%	216%	287%	347%
2	-29%	0%	22%	41%	58%	124%	174%	216%
3	-42%	-18%	0%	15%	29%	83%	124%	158%
4	-50%	-29%	-13%	0%	12%	58%	94%	124%
5	-55%	-37%	-23%	-11%	0%	41%	73%	100%
10	-68%	-55%	-45%	-37%	-29%	0%	22%	41%
15	-74%	-63%	-55%	-48%	-42%	-18%	0%	15%
20	-78%	-68%	-61%	-55%	-50%	-29%	-13%	0%

Types of Warehouse Operation

Section 3

Functions of a warehouse

- Inventory holding point - Stock is held to fulfil orders / demand.

  Provide a buffer stock, preparation for a new product launch, facilitate long production runs

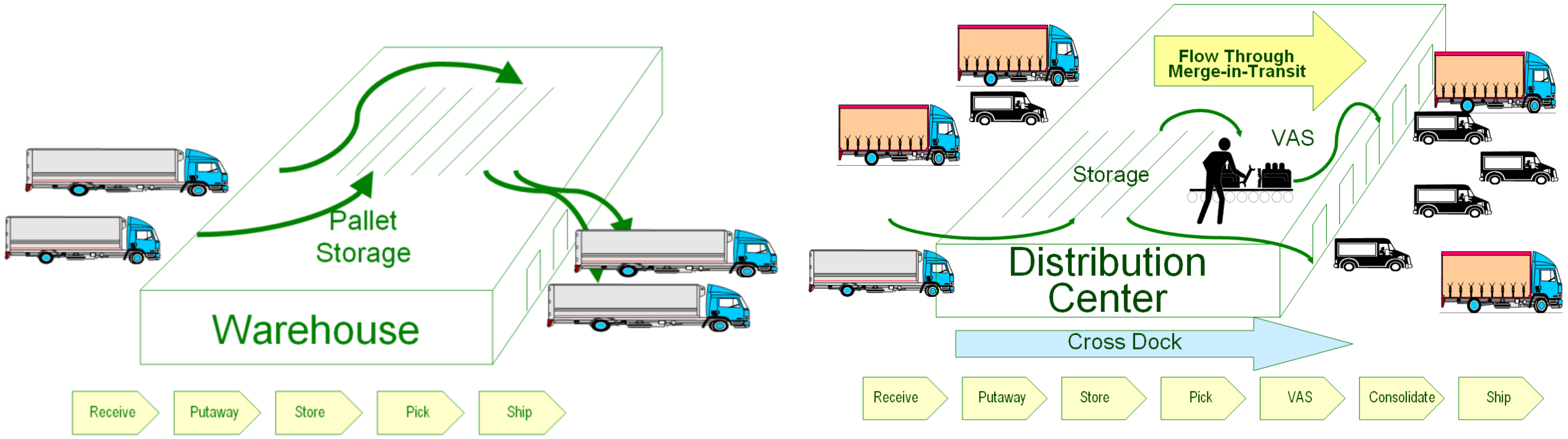
  Storage of Customs and excise goods under bond

Other types

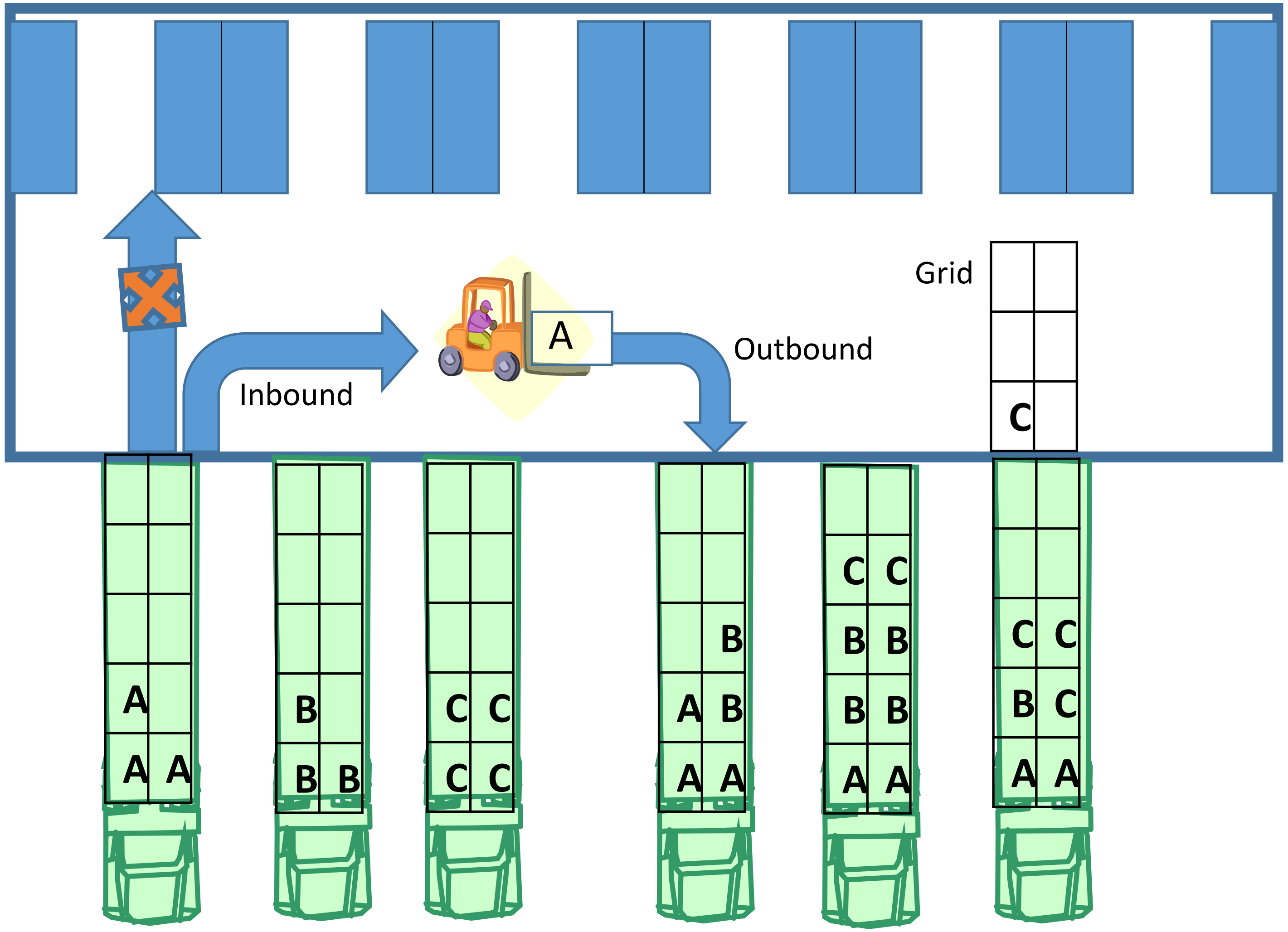
- Sequencing centre - Just in time related techniques
- Consolidation centre - Product lines from various locations are consolidated into complete customer orders.
- Cross-dock centre - Goods are received and shipped onwards without storage.
- Sortation centre - Goods are sorted by customer or region. (parcels/pallets)
- Sub-Assembly facility - Final assembly of goods prior to distribution e.g. postponement or labelling.
- Trans-shipment point - Goods are sorted into smaller vehicle loads for delivery to the customer – break-bulk centre.
- Fulfilment centre e-commerce and catalogue sales
- Returned goods centre - To handle returned / faulty goods.

Warehouse Types

- Local, regional, national, international stock holding points



Cross dock operation



Ambient storage (room temp storage)

Photo – Newman Paperboard

Photo – Howard Tenens

Hazardous Goods storage

Photo - EDIE

Photo – Transmare - chemie

There are nine classes, some with divisions, as follows:

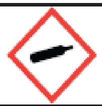
UN Class	Dangerous Goods	Division(s)	Classification
1	Explosives	1.1 - 1.6	Explosive
2	Gases	2.1	Flammable gas
		2.2	Non-flammable, non-toxic gas
		2.3	Toxic gas
3	Flammable liquid		Flammable liquid
4	Flammable solids	4.1	Flammable solid
		4.2	Spontaneously combustible substance
		4.3	Substance which in contact with water emits flammable gas
5	Oxidising substances	5.1	Oxidising substance
		5.2	Organic peroxide
6	Toxic substances	6.1	Toxic substance
		6.2	Infectious substance
7	Radioactive material		Radioactive material
8	Corrosive substances		Corrosive substance
9	Miscellaneous dangerous goods		Miscellaneous dangerous goods

Packaging and Labelling

The consignor is responsible for ensuring that the packaging conforms to the regulations for the product. The packaging can be as simple as a cardboard box or paper bag for low risk powders in small quantities to very sophisticated double skinned stainless steel packages for more complex high risk products. In general the package needs to be UN approved and compatible with the product but for every UN number there is a list of packaging options available to the packer.

Having packed the product the package has to be labelled, this is not about the product labelling or CHIP labelling which has health and safety advice for the user, but a rather simple class warning symbol. On small packages a 100 mm square coloured diamond with a symbol, these can be larger on IBC's and road tankers. I have illustrated a couple of examples below:

New Haz chem codes

	Example of hazard statement	Example of precautionary statement
	Heating may cause an explosion	Keep away from heat/ sparks/open flames/ hot surfaces – no smoking
	Heating may cause a fire	Keep only in original container
	May intensify fire; oxidiser	Take any precaution to avoid mixing with combustibles
	Causes serious eye damage	Wear eye protection
	Toxic if swallowed	Do not eat, drink or smoke when using this product
	Toxic to the aquatic life, with long lasting effects	Avoid release to the environment
	**New pictogram**, reflects serious longer term health hazards such as carcinogenicity and respiratory sensitisation eg May cause allergy or asthma symptoms or breathing difficulties if inhaled	In case of inadequate ventilation, wear respiratory protection
	**New pictogram**, refers to less serious health hazards such as skin irritancy/sensitisation and replaces the CHIP  symbol eg May cause an allergic skin reaction	Contaminated work clothing should not be allowed out of the workplace
	**New pictogram**, used when the containers hold gas under pressure eg May explode when heated	None

Temperature controlled storage

Photo by fordsproduce.com

Photo by Texas ice house

Bulk storage

Garment storage

Photo by Asda Walmart

Photo by Transformer

Archive Storage – Abandoned Salt mines

Fulfilment Centres

Photo by BBC News - Amazon

Other Warehouse examples

Warehouse types

Open spaces can also be classed as warehouses if products are stored for a period

Returns/Recycling warehouse

J & M Re-cycling

http://your.asda.com/sustainability-store-waste/waste-not-want-not-2

Customs warehousing - advantages

- Customs warehousing is a procedure that enables the suspension of Import Duty and/or VAT.
- Delay paying import duty and/or VAT and excise duty on your stocks of imported goods.
- If you want to re-export you don’t pay import tax
- If you do not know the ultimate destination of the imported goods and want to delay having to declare imported goods to another customs procedure, for example release for free circulation
- Certain countries operate Free Trade Zones on a similar principle

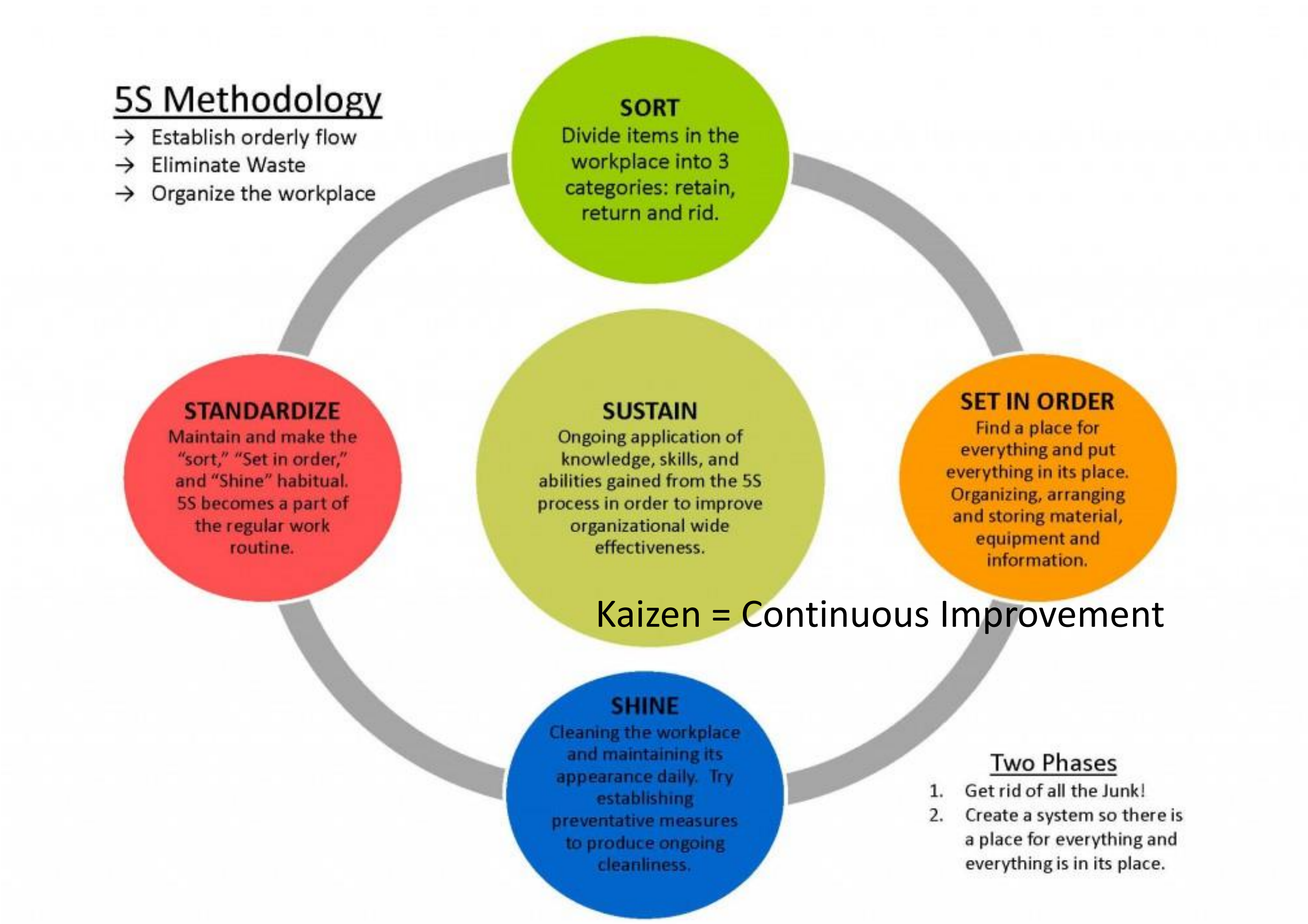
HM Revenue and Customs requirements

- The warehouse will be used primarily for the storage of goods
- There is a genuine economic need
- Your stock records are adequate to verify the receipt, storage, handling and disposal of the goods and they must be able to show at all times the current stock of goods that are held under the customs warehouse procedure.
- You must be solvent and have a compliant revenue record
- You must use it regularly

Warehouse Processes Part 1

Section 4

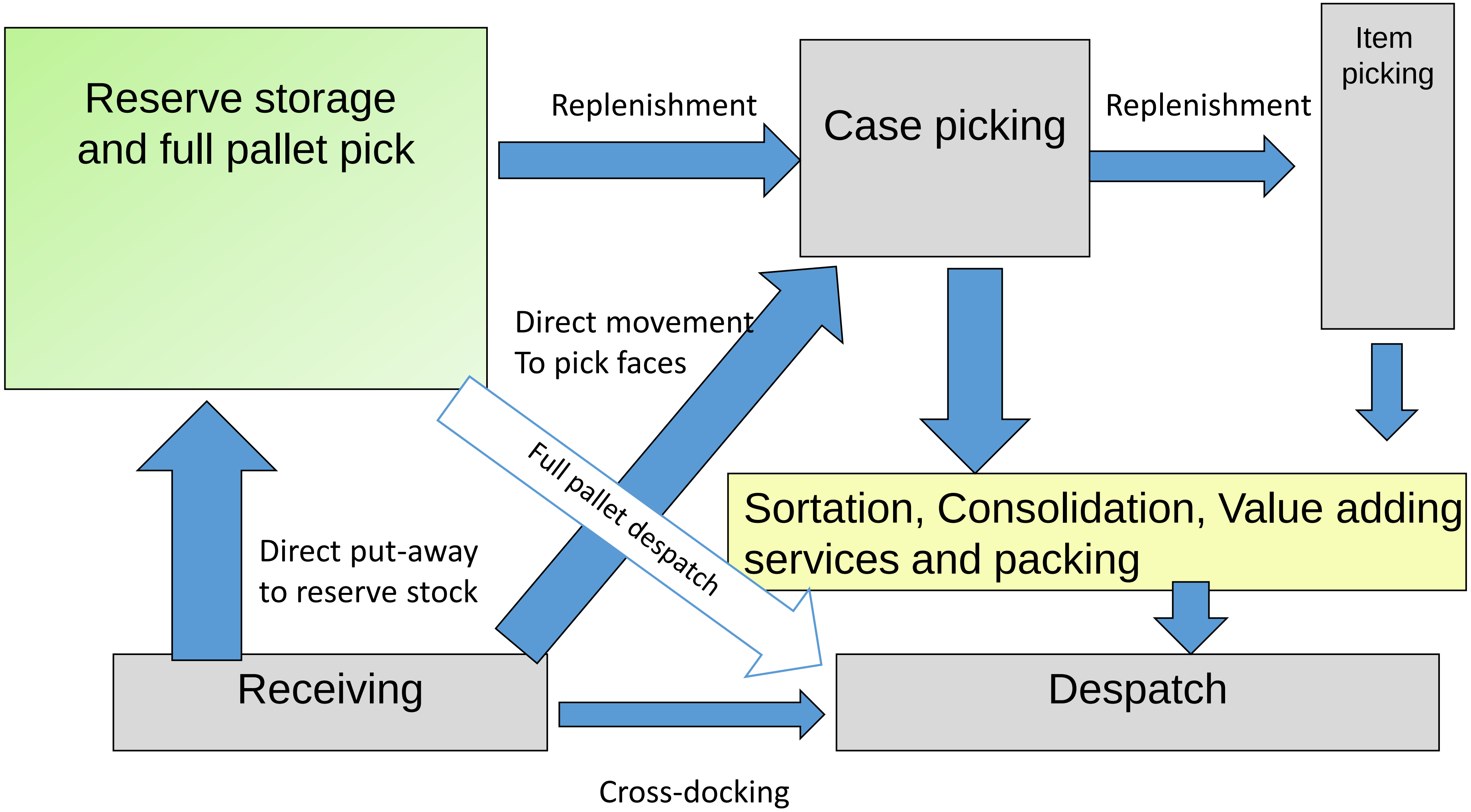
Lean Warehousing



Cerasis.com

Shadow boards

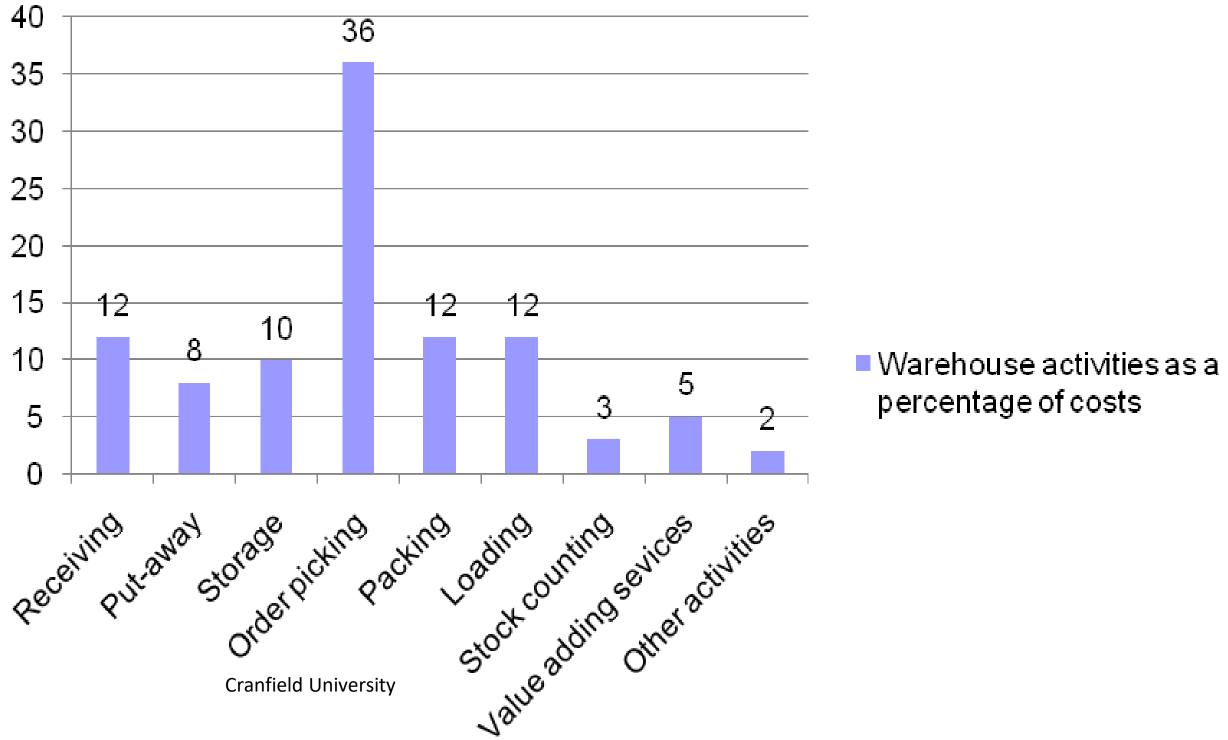
Warehouse processes and flow



Adapted from Schmidt & Follert 2011

Warehouse functions

- Goods inward/receipt
- Inward sortation and Cross-docking
- Storage
- Replenishment
- Order picking
- Secondary sortation
- Collation
- Postponement
- Value adding services
- Despatch
- Housekeeping
- Stock counting
- Returns processing



Cranfield University

Pre-receipt

- Agree specifications with supplier
- Inform supplier of requirements reg
  - Size and type of delivery vehicle
  - Size and type of pallets
  - Size of cartons
  - Labelling requirements
  - Delivery documentation
  - Pre-notification
  - Delivery procedures
    - Unloading requirements
    - Role of the driver

Pallets

- Pallet rental companies
  - Charged on a pence per day basis
  - Pallets are normally in very good condition
  - Does require both suppliers and buyers to be part of the rental scheme
  - Removes requirement to collect pallets from customers

V

Pallet Dimension *(Continued…)*

The following website provides a tool for calculating the pallet dimension and weight as well

http://onpallet.com

- Open this website and play with the web page using different dimensions and weights.

Checking in Loads

- TiHi describes the arrangement of cases on a pallet.
- It stands for Timarandum Height or ‘layers of’ × height.
- ‘Ti’ means the number of boxes or cases in a pallet layer.
- ‘Hi’ means the number of layers high on a pallet.

- **TiHi** refers to the number of boxes/cartons stored on a layer, or **tier**, (the Ti) and the number of **layers high** that these will be stacked on the pallet (the Hi)

Checking in Loads

Example:

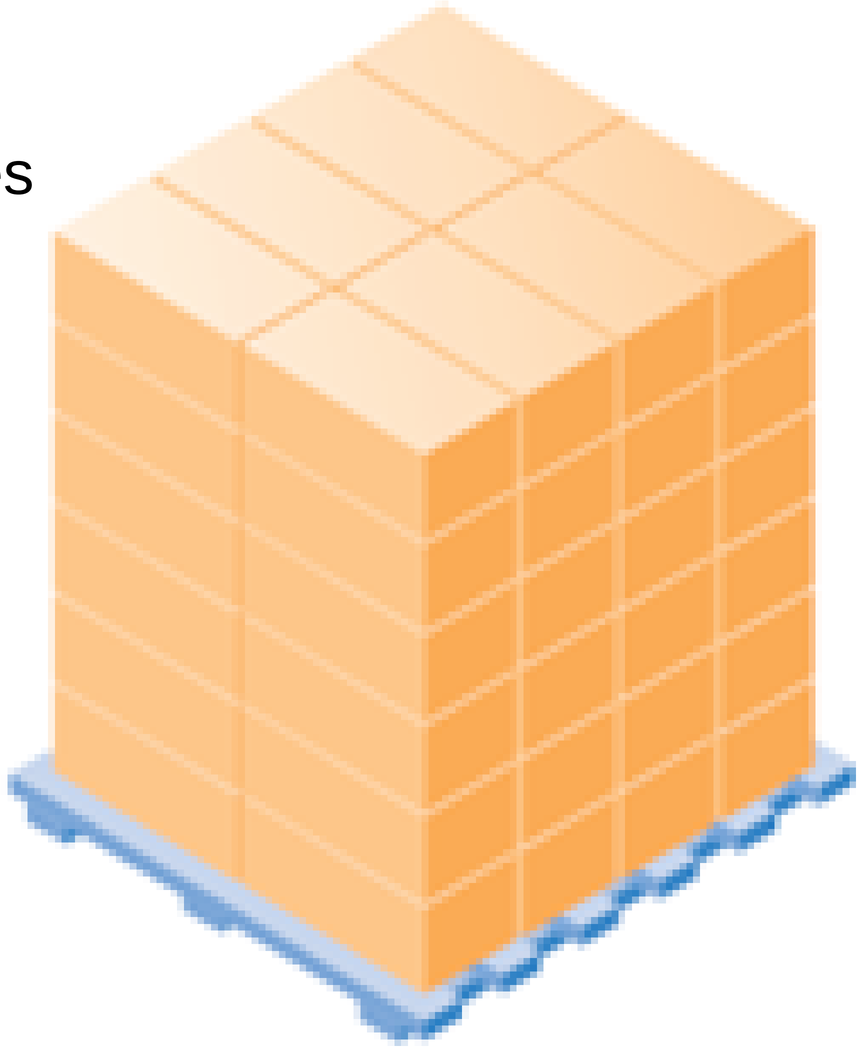
➢A TiHi of 8 × 6 means 8 cases per layer; 6 layers high.

Ti and Hi →

Ti × Hi = Pallet quantity

TiHi = **8 × 6**

Pallet quantity = **48**



Checking in Loads

When pallets arrive, the **TiHi** must be the same as on the delivery note.

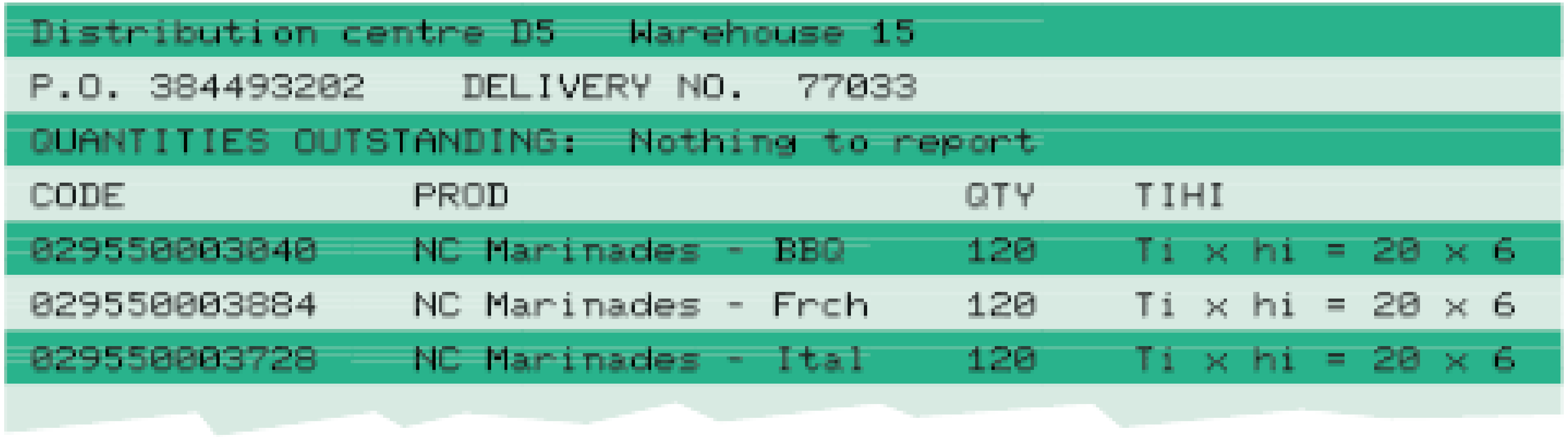
Imagine this:

Pallet A = 120 cases with a TiHi of 20 × 6

Pallet B = 120 cases identical to those on pallet A, but with a TiHi of 6 × 20

- ➢ Which TiHi gives the taller pallet?
- ➢ Which TiHi gives the larger ‘footprint’?
- ➢ How many cases make this larger ‘footprint’?

Checking in Loads



Distribution centre D5 Warehouse 15

P.O. 384493202 DELIVERY NO. 77033

QUANTITIES OUTSTANDING: Nothing to report

CODE	PROD	QTY	TIHI
029550003040	NC Marinades - BBQ	120	Ti x hi = 20 x 6
029550003884	NC Marinades - Frch	120	Ti x hi = 20 x 6
029550003728	NC Marinades - Ital	120	Ti x hi = 20 x 6

What problems might occur if a tihi of 6 × 20 is accepted when a tihi of 20 × 6 is on the delivery sheet?

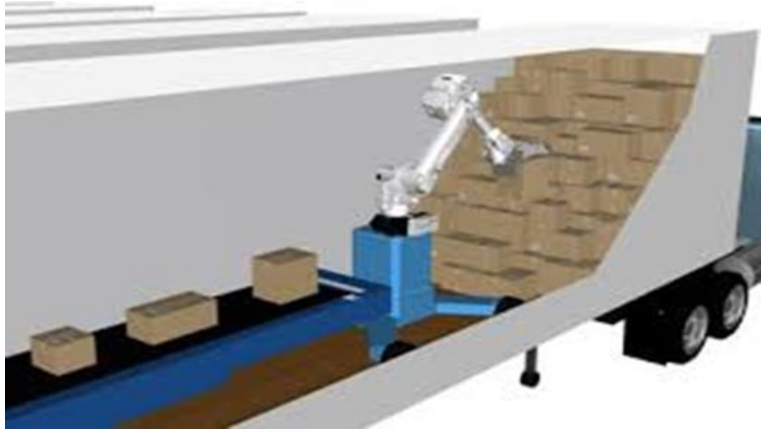
Receiving

- Allocate the supplier a time for delivery
- Estimate time to unload, check and put-away
- Allocate sufficient labour and MHE for unloading
- Check if load requires special handling
- Check for any special handling instructions (Hazardous, fragility etc)
- Unload and check quantities and quality of delivery
- Record variances
- Check status of goods
- Label or ID tag
- Record quantities
- Clear dock area and ensure goods are on system and available to pick – dock to stock time is crucial!
- Locate - Quarantine, cross dock, pick face, reserve storage

Booking in sheet

DOOR One							
Time slot	Supplier	Units	Unit type	Time estimate	Eqpt	Actual time	Comments
0700	ARCO	24	Pallets	45 mins	PPT	40 mins	Vehicle was 2 hours late
0750	TCO Deli	10	Parcels	10 mins		10 mins	Urgent delivery
0805	SBH Ltd	12	Pallets	24 mins	PPT	25 mins	
0835	Delta ltd	24	Pallets	45 mins	PPT	45 mins	
0925	Argo.com	1000	cases	3 hours x 3 staff	FLT	2hrs 50 mins x 3	Container

In-handling equipment



Dock Equipment

Dock Levelers

- Hydraulic
- Air Bag
- Mechanical
- Power Assisted

- Bumper Pads
- Dock Shelters
- Dock Lights
- Safety lights/warnings
- Operating procedures
- Signage in different languages

Labelling and Put-away

- Ensure supplier has labelled products correctly
- Produce own labels although not as efficient
- Scan labels
- System determined put-away
- Location allocation by system or manual
- Take into account size, weight, velocity, compatibility
- Quarantine areas
- Fixed or random locations?
- Check stock rotation policy
- Consolidate stock if FIFO rules allow
- Record stock against the location
- Task interleaving or dual cycling – put-away and retrieve in same movement

Inbound and put away processes

Inbound check

Location verification and put-away

WMS

Fixed v Random storage

Fixed locations total = 453

Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
K1	100	155	100	140	100	120	120	100	100	120	150	150
K2	50	20	51	30	30	30	40	50	50	40	40	50
K3	10	5	12	17	10	10	5	10	10	5	5	10
K4	90	80	80	75	75	75	80	80	95	90	80	90
K5	40	40	50	50	135	130	130	130	50	40	40	40
SUM	290	300	293	312	350	365	375	370	305	295	315	340

Random locations

Packaging

- Be involved when initially discussing new products
  - It's not all about the product!! – think about the packaging!
- Nature of the product – size, selling quantities, hazard, cost
- Arrival packaging, returnable plastic pallets, stillages etc
- Labelling
- Nature of storage medium
- Despatch quantities
- Recycled packaging

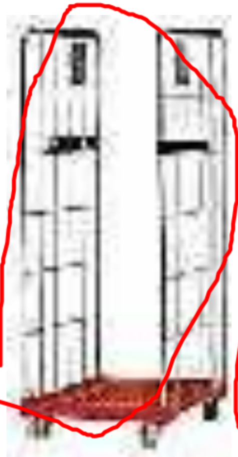
The protective packaging company

Unitisation

- An approach aimed at creating an appropriate standard module for handling, storage, movement, loading and unloading during the transport and distribution process.
    - Small containers used in small parts storage and handling.
    - Wooden pallets which have become a key unit load within the EU market.
    - Totes and Dollies
    - Cage and box pallets
    - Roll cage pallets used in wholesale operations, e.g. grocery distribution
    - Stillages – used in automotive
    - Intermediate bulk containers in ranges of one to two tonnes payloads







The importance of Unit Loads

Used by manufacturers, retailers and service providers, unit loads are key cost drivers. They impact on transport, storage, handling and packaging, which together represent 12-15% of the retail sales price.

Developing more Efficient Unit Loads is critical to the success of Efficient Consumer Response and is estimated to save 1.2% of the retail sales price.

E.g. Prescribed length and width is seen as a must by manufacturers and retailers, with the 600x400 master module accepted as the basis in Europe for 1200 x 800mm pallets.

Order Picking Methods

- Paper pick lists
- Pick by label
- Pick by voice https://www.youtube.com/watch?v=yy53EMEmx_c https://www.youtube.com/watch?v=BcbhbGRXZRE
- Barcode scanning https://www.youtube.com/watch?v=CJW5D5SDAgw https://www.youtube.com/watch?v=Xe7UaH20n7A https://www.youtube.com/watch?v=86ttdESB9_g
- Radio Frequency identification https://www.youtube.com/watch?v=gEQJxNDSKAE
- Pick By light /Pick to light https://www.youtube.com/watch?v=tPIQpKi_-Ko

Location I.D.

- 4 E 14 C 1 or
- 04.05.14.03.01

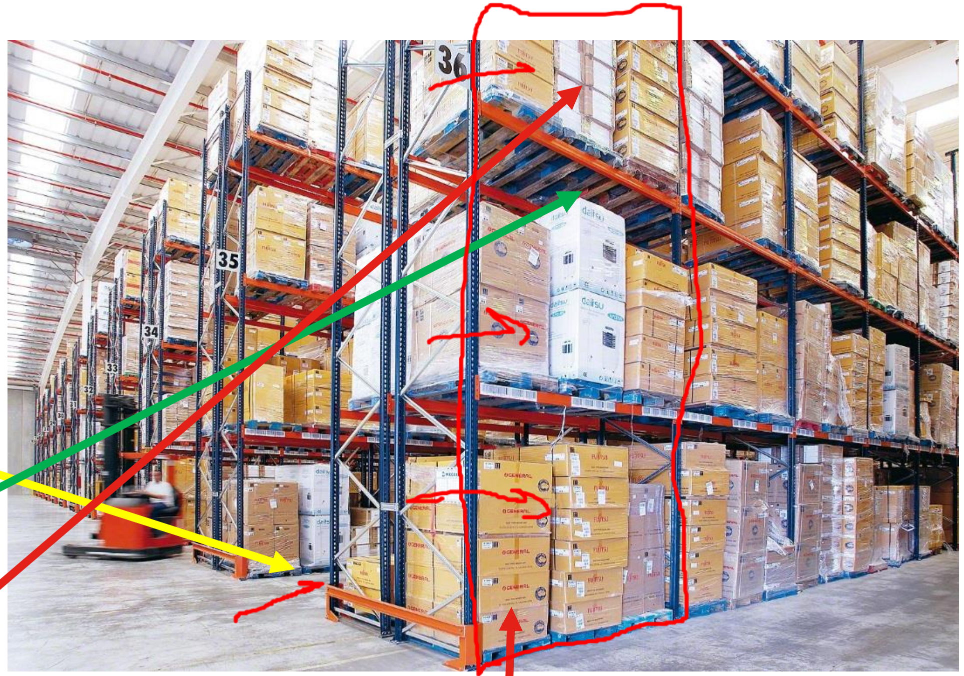
Where 4 (04) = zone

E (05) = Aisle

14 = Bay

B (03) = Level

1(01) = Pallet, Shelf or bin position



Picking systems

- Picking is paramount to any warehouse operation
  - It is the most labour intensive
  - It is fundamental to customer service
  - There are often extensive floor space requirements
  - There may be limited scope for automation

On average up to 65% of the warehouse operating expenses can be attributed to the Picking function.

On average travel time accounts for 50% of the total picking time (Petersen C.G. 2002).

Pick volumes

Picking – The set up

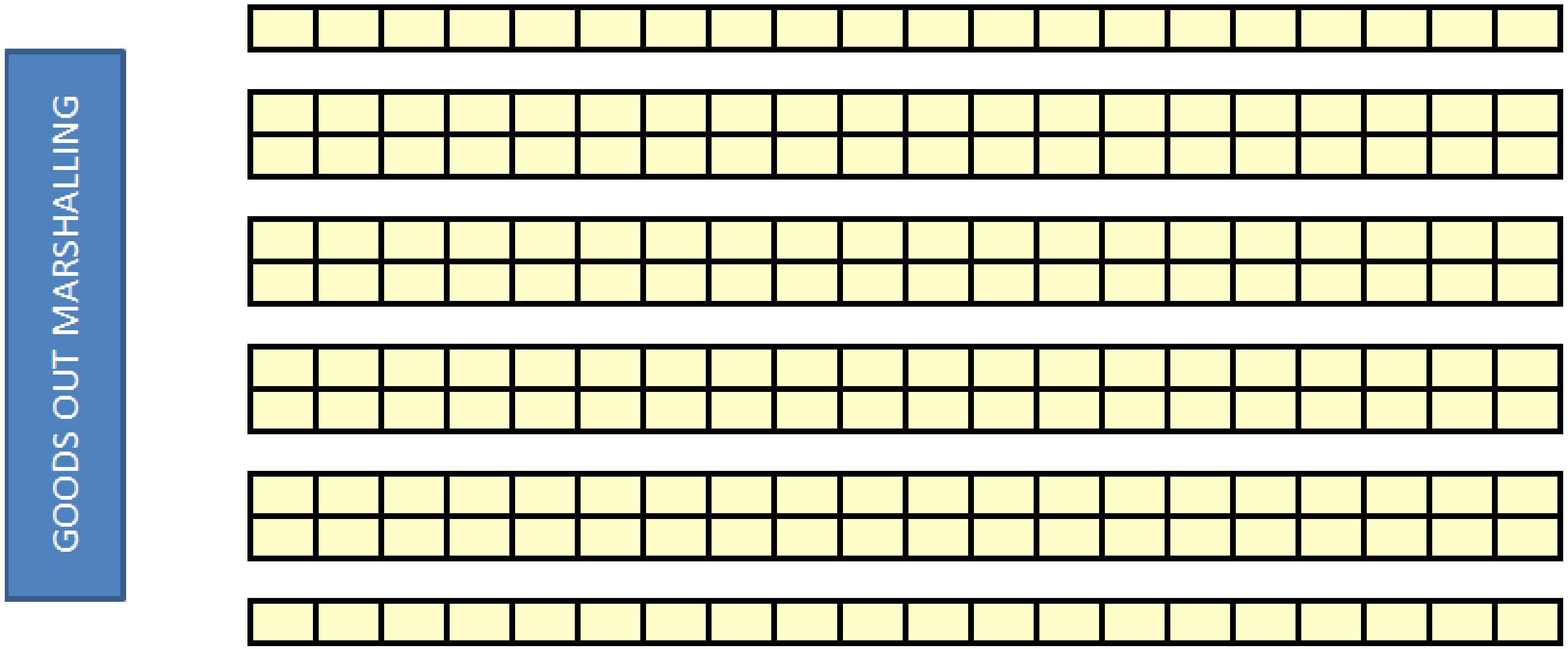
Pareto or the 80/20 rule

- Sales (80% of sales from 20% of product lines)
- Sales (20% customers provide 80% of sales)
- Suppliers (80% of volume from 20% of suppliers)
- Value of product (20% of product lines – 80% of value)
- Cost of servicing clients (20% of clients – 80% of problems)
- Labour (20% of staff – 80% of problems)
- Labour (80% of efficiency from 20% of staff)

ABC/Pareto Analysis

Ranking *(by frequency)*	***Order frequency in period***	***Cumulative frequency***	***Cumulative % of total frequency***	***Cumulative % of number of stock lines***	***Category***
1	300	300	30	5	A
2	225	525	52.5	10	A
3	150	675	67.5	15	A
4 *	125 *	800 *	80	20	A
5	40	840	84	25	B
6	30	870	87	30	B
7	25	895	89.5	35	B
8	25	920	92	40	B
9	15	935	93.5	45	B
10	15	950	95	50	B
11	10	960	96	55	C
12	8	968	96.8	60	C
13	6	974	97.4	65	C
14	5	979	97.9	70	C
15	5	984	98.4	75	C
16	4	988	98.8	80	C
17	4	992	99.2	85	C
18	3	995	99.5	90	C
19	3	998	99.8	95	C
20	2	1,000	100	100	C

Why is ABC Analysis Important?

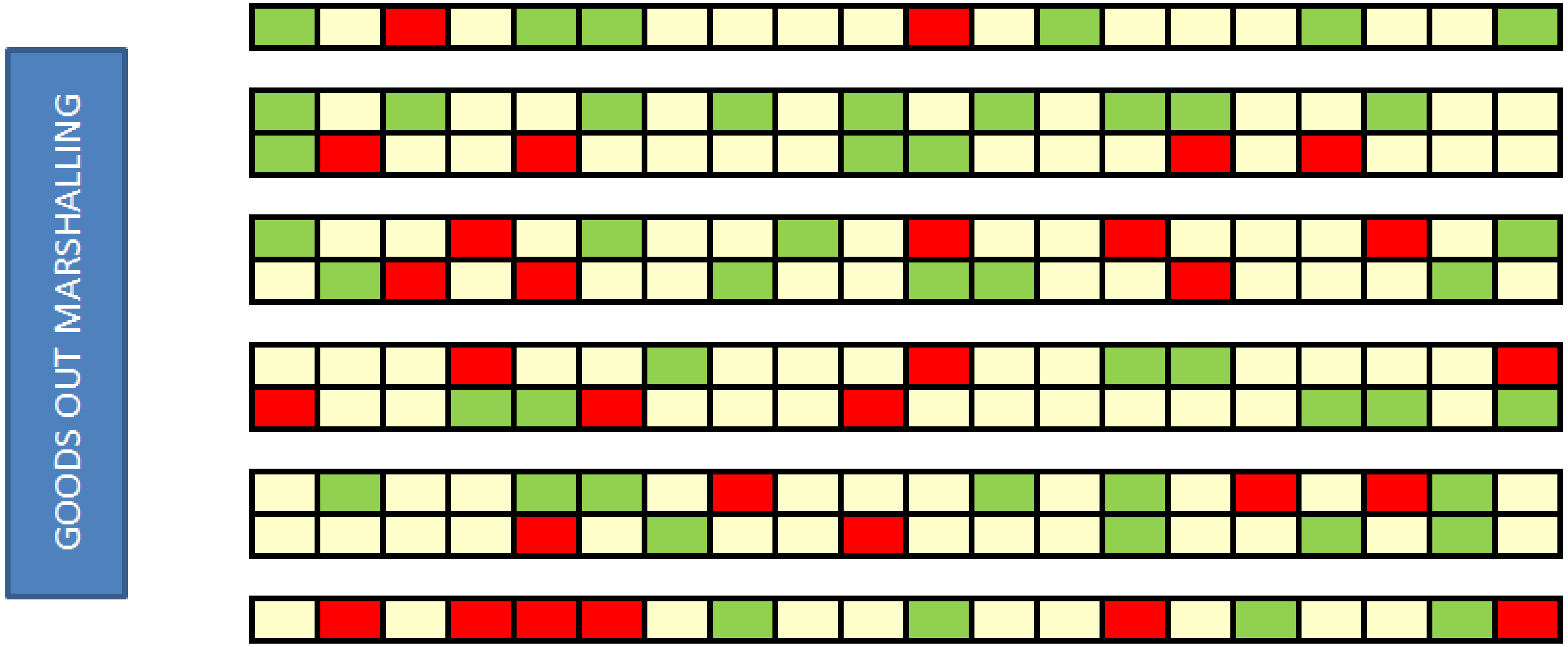


Take an example:

200 full pallet, ground floor pick positions

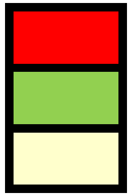
5 aisles

Why is ABC Important ?

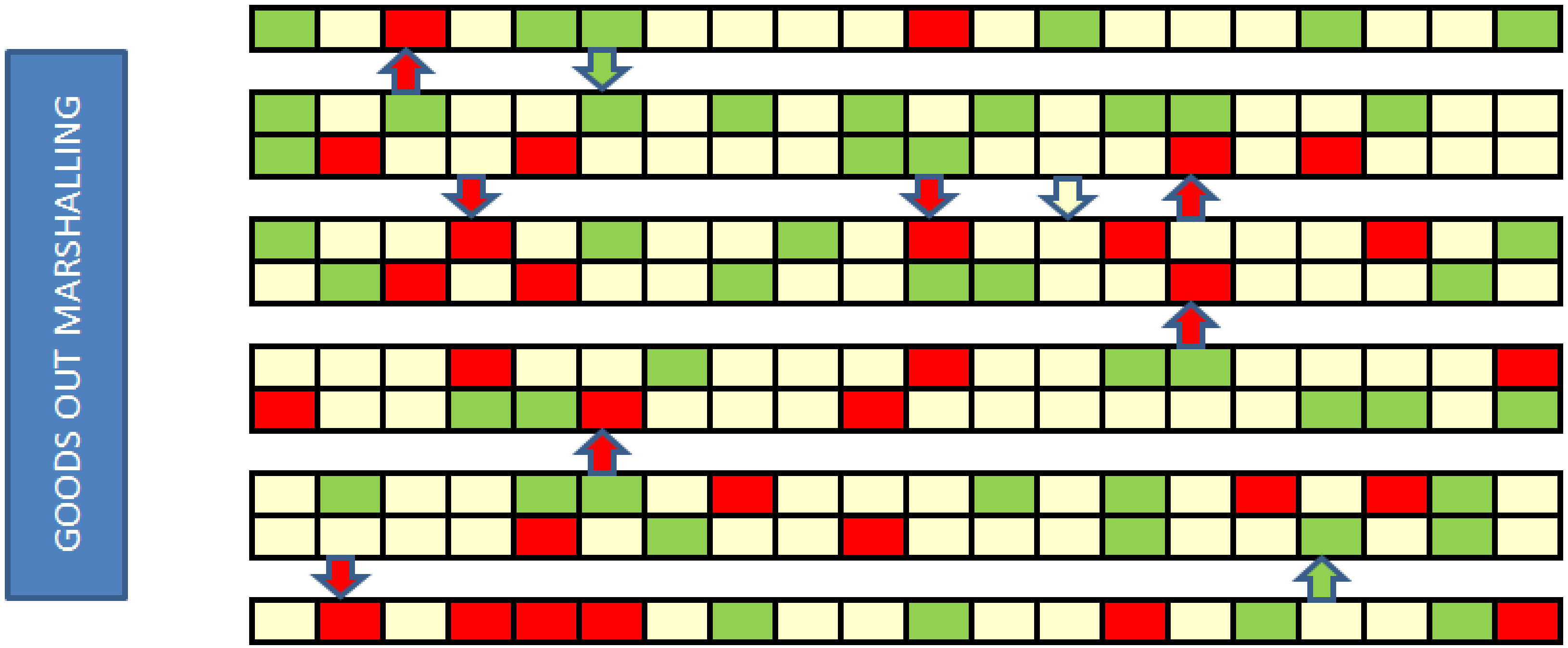


Apply sku –
ABC Analysis

200 Positions		
A	15%	30
B	25%	50
C	60%	120



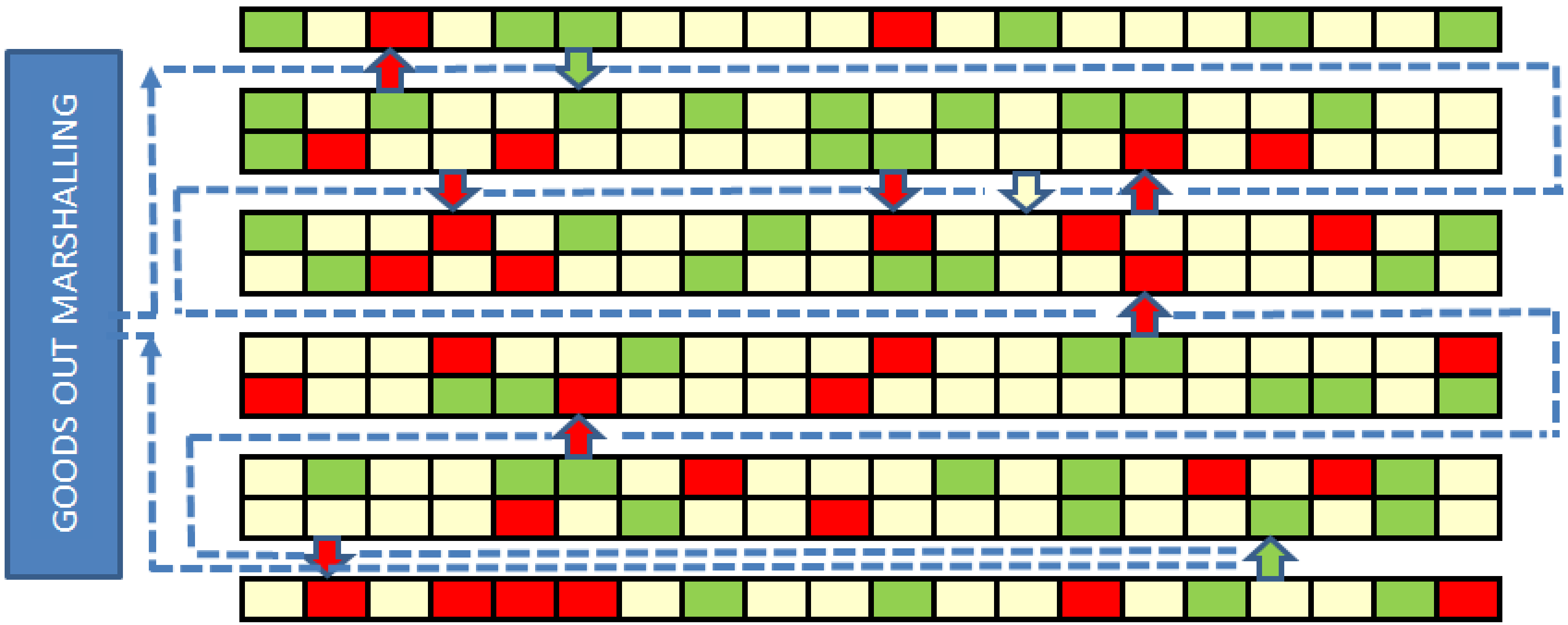
Why is ABC Important?



Freq	10 item order
70%	7
20%	2
10%	1

Generate a 10 Item Pick

Why is ABC Important?



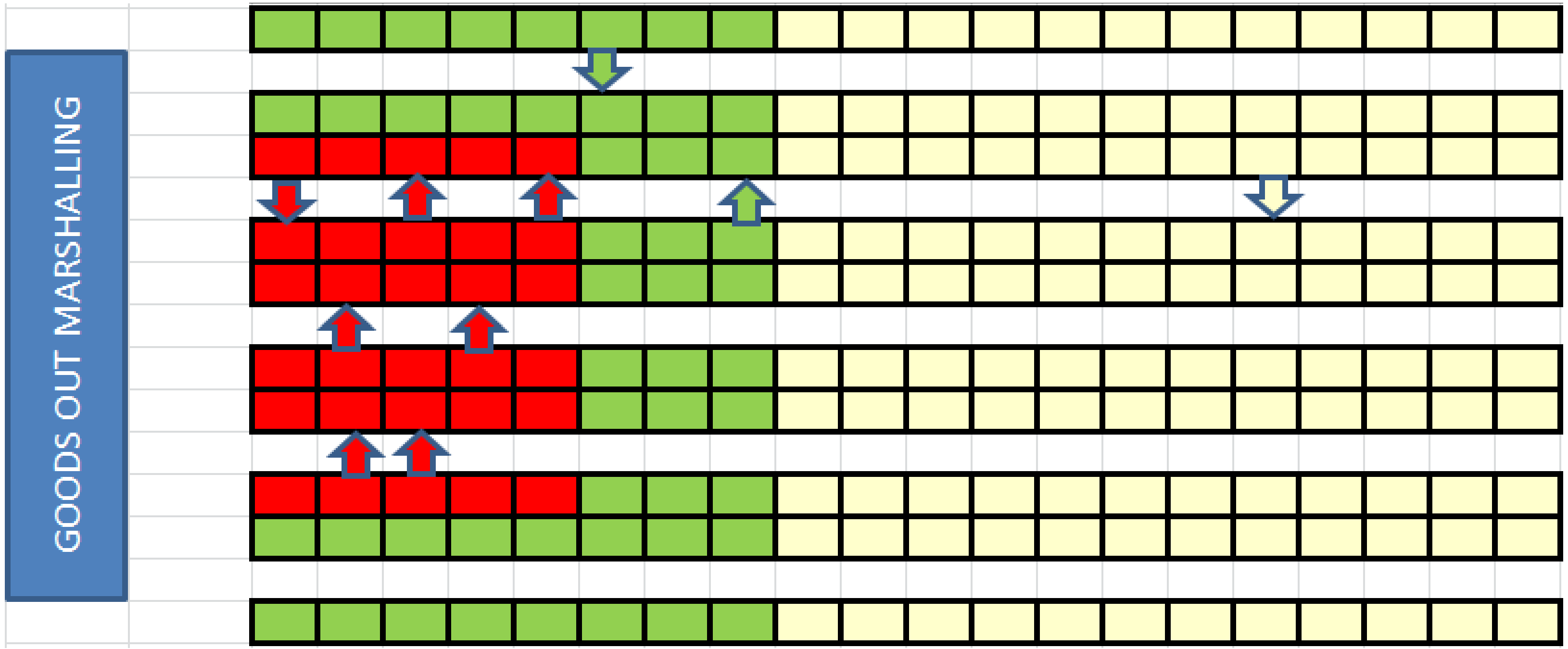
Add the Route

Pick Journey (secs)

	Horizontal		Vertical	
	Bays	End Bays	Bays	Aisles
	112	10	16	5
Bay Width	1.5	1	1	3
Distance	168	10	16	15
				209
			Speed (m/sec)	1.0
			Journey time (sec)	209

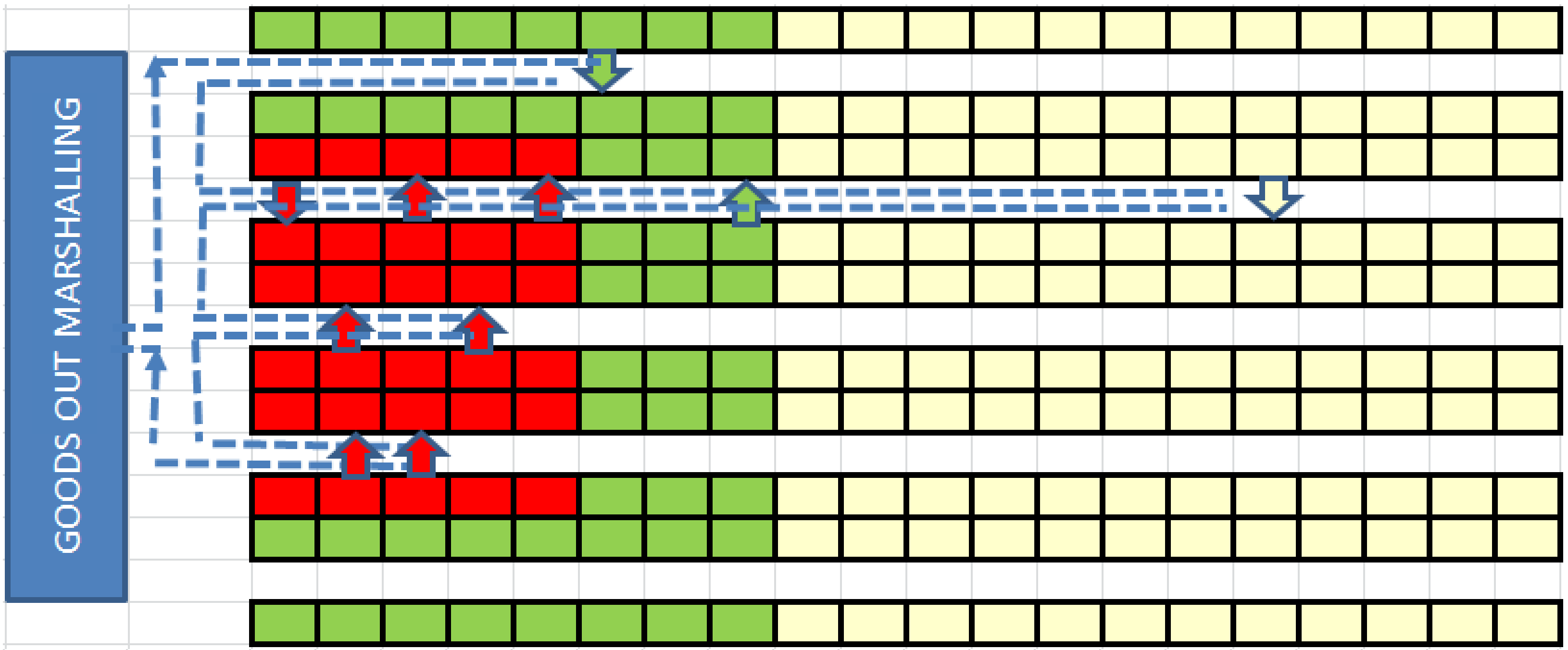
Travel Time: 209 seconds

Why is ABC Important?



Apply a Slotting Strategy

Why is ABC Important?



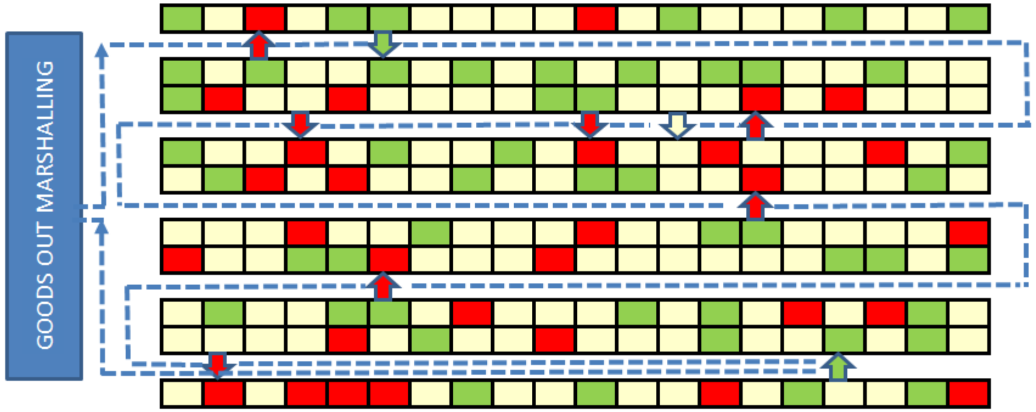
Shorter Distances

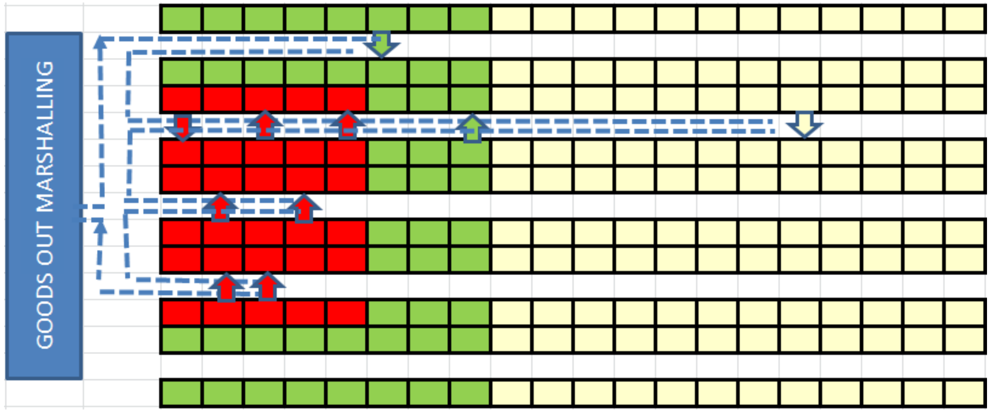
	Pick Journey (secs)			
	Horizontal		Vertical	
	Bays	End Bays	Bays	Aisles
	58	8	12	3
Bay Width	1.5	1	1	3
Distance	87	8	12	9
				116
			Speed (m/sec)	1.0
			Journey time (sec)	**116**

Reduced Travel Time

116 sec vs 209 sec

% Benefit





	Slotting	Non-Slotting
Journey Time	116	209
Pick Time (10 items @ 7.5 sec)	75	75
Start & End	70	70
Total	**261**	**344**

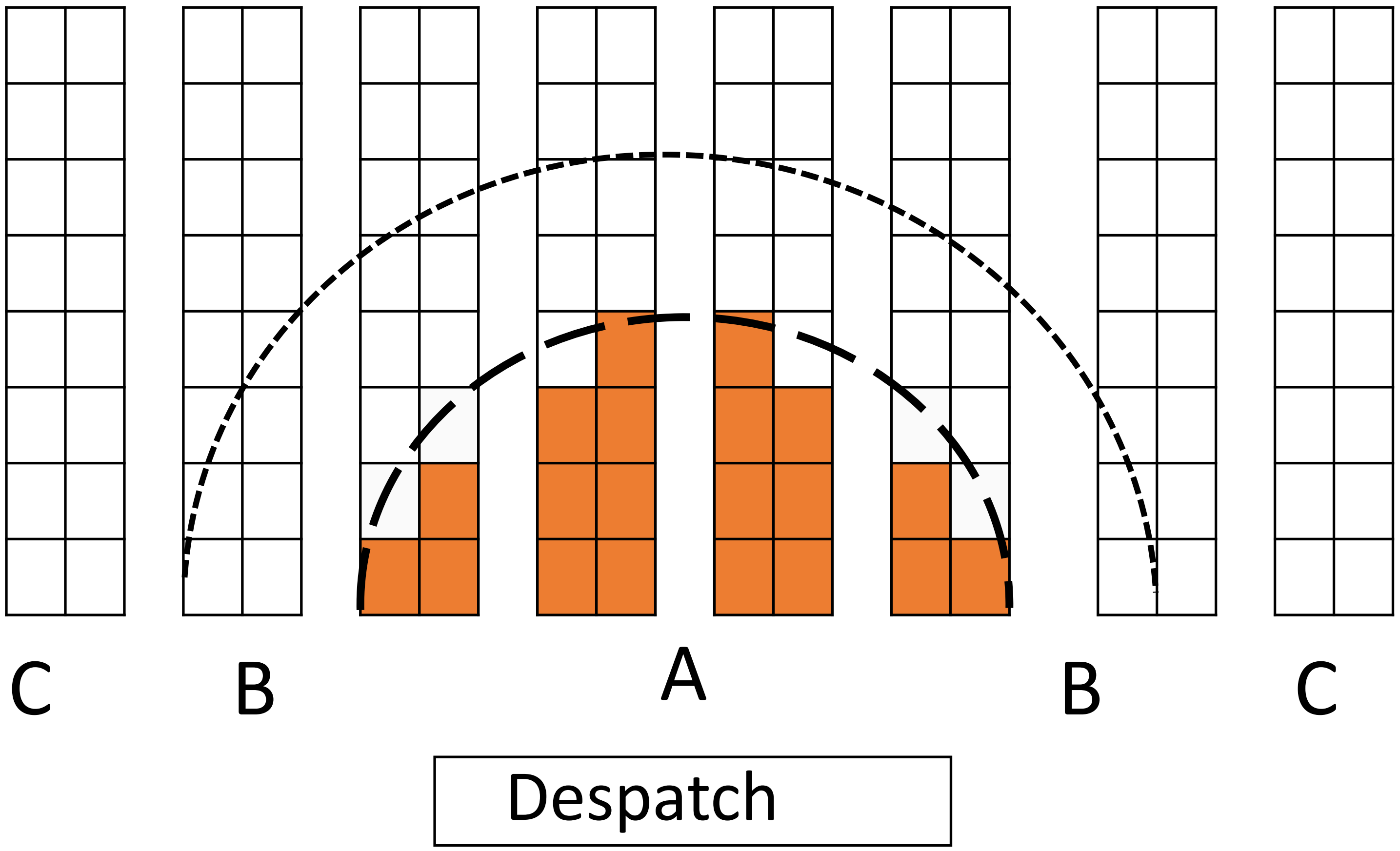
Courtesy of Cirrus Logistics

ABC layout

C Zone
Slow movers
45% SKU,
5% frequency

B Zone
Medium movers,
35% SKU,
15% of frequency

A Zone
Fast movers,
20% SKU, 80%
of order
frequency

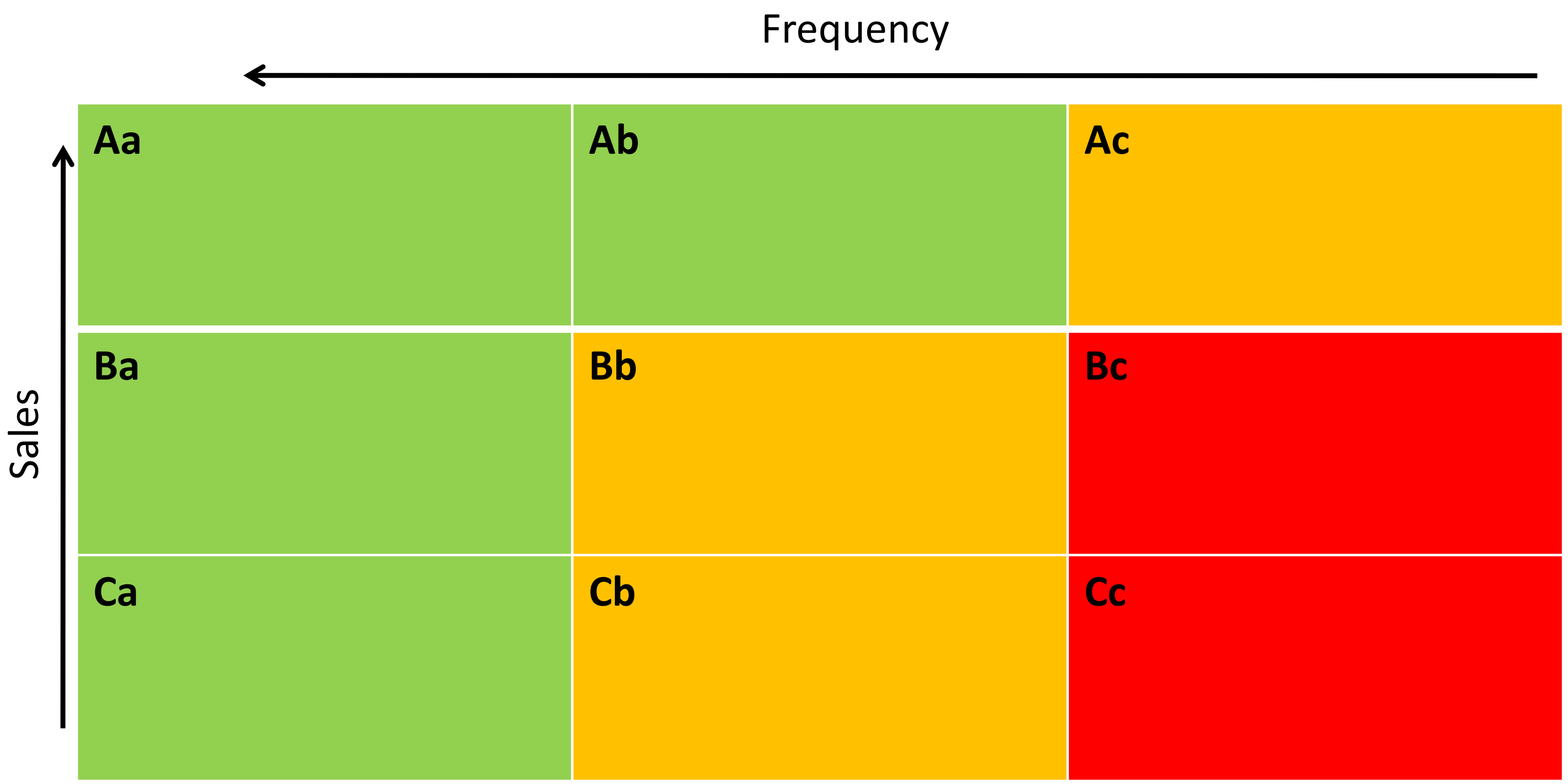


Actual example (1350 stock items in total)

	No.Orders	Cumulative	Cumulative %	Current stock	Stock item Y/N	ABC	Pallet/shelf
CC214	1600	1600	4.94	317	Stock	A	Pallet
CC208	1166	2766	8.55	107	Stock	A	Pallet
CC216	1099	3865	11.94	117	Stock	A	Pallet
BC301	1055	4920	15.21	60	Stock	A	Pallet
CC114	731	5651	17.46	119	Stock	A	Pallet
BC028	728	6379	19.71	20	Stock	A	Pallet
BC010	715	7094	21.92	42	Stock	A	Pallet
BC031	626	7720	23.86	5	Stock	A	Pallet
KE977	549	8269	25.56	382	Stock	A	Pallet
KE976	547	8816	27.25	128	Stock	A	Pallet
CC116	521	9337	28.86	68	Stock	A	Pallet
CC109	521	9858	30.47	83	Stock	A	Pallet
BC296	501	10359	32.01	0	Stock	A	Pallet
BC300	355	10714	33.11	10	Stock	A	Pallet
KE978	352	11066	34.20	592	Stock	A	Pallet
BC302	343	11409	35.26	11	Stock	A	Pallet
CC217	343	11752	36.32	44	Stock	A	Pallet
BC011	315	12067	37.29	18	Stock	A	Pallet
BC503	312	12379	38.26	10	Stock	A	Pallet
BC012	285	12664	39.14	18	Stock	A	Pallet

270 stock items produced 80% of the orders!

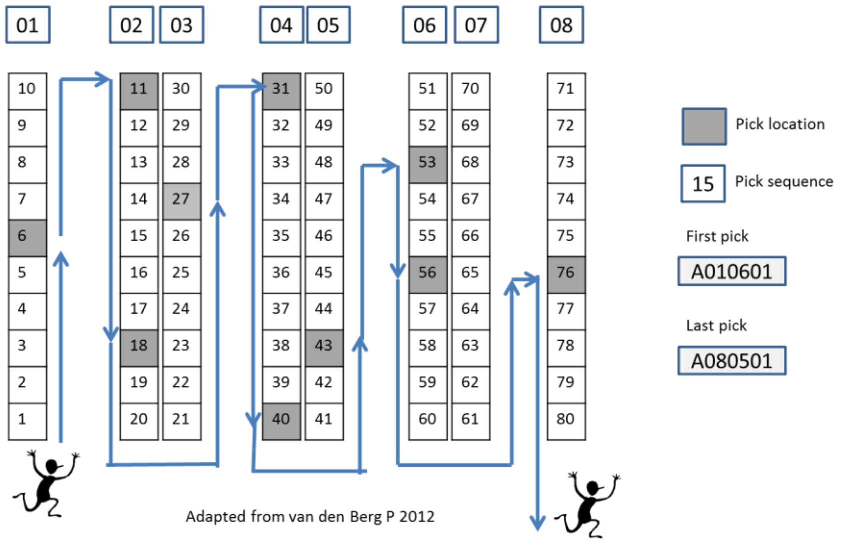
ABC Analysis – volume and frequency

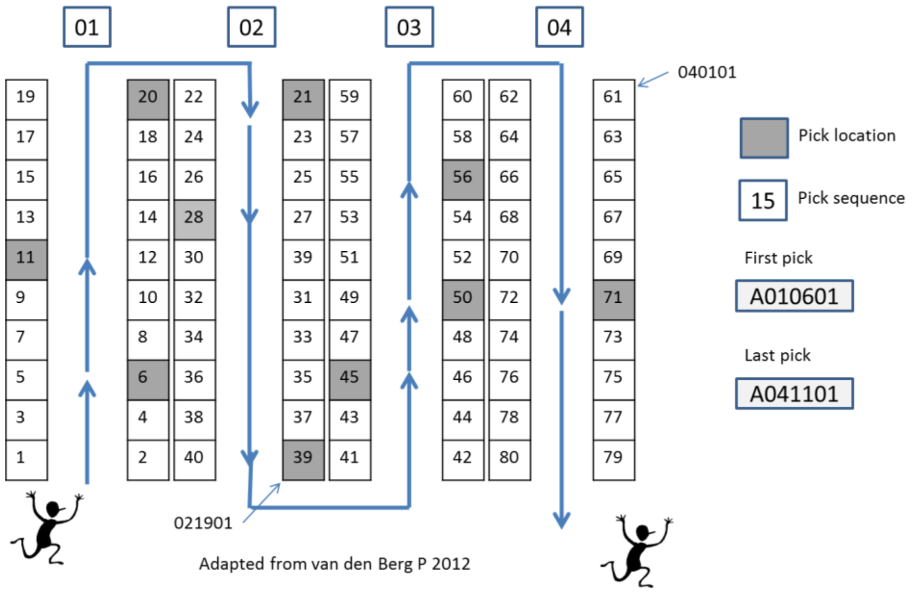


Ac – products sold less frequently but with high impact on sales
Ca – Products sold often but in fewer quantities

Pick face examples

Pick sequence and aisle numbering



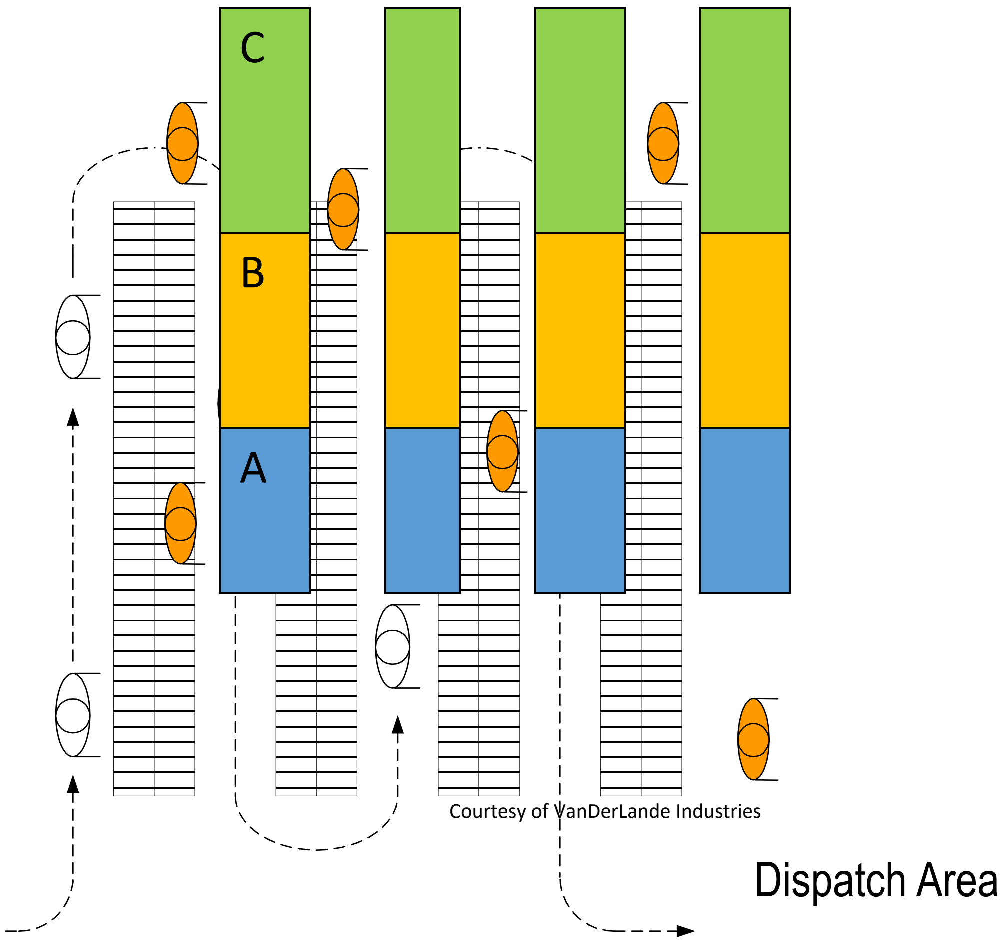


Picking procedures

- Pick by order
  - All lines are collected for a specific customer order
    - Minimal handling, order sizes are typically high.
- Pick by label
  - All lines are collected for a specific customer order and labels attached to each item during the picking process
    - Minimal handling, order sizes are typically high.
- Cluster picking
  - Take several individual orders out at the same time
    - Can be confusing without technology
- Pick by batches
  - Products collected for a large number of orders with the same product lines
    - Fewer runs but increased handling and sortation, mainly large quantities of small orders
- Pick by zones
  - Products are categorised into specific groups and picked from defined areas
    - Reduced walking distance, increased sortation
- Pick by waves
  - Large batches of orders are collected for defined time periods e.g. arrival of vehicle

ORDER PICKING – individual and cluster

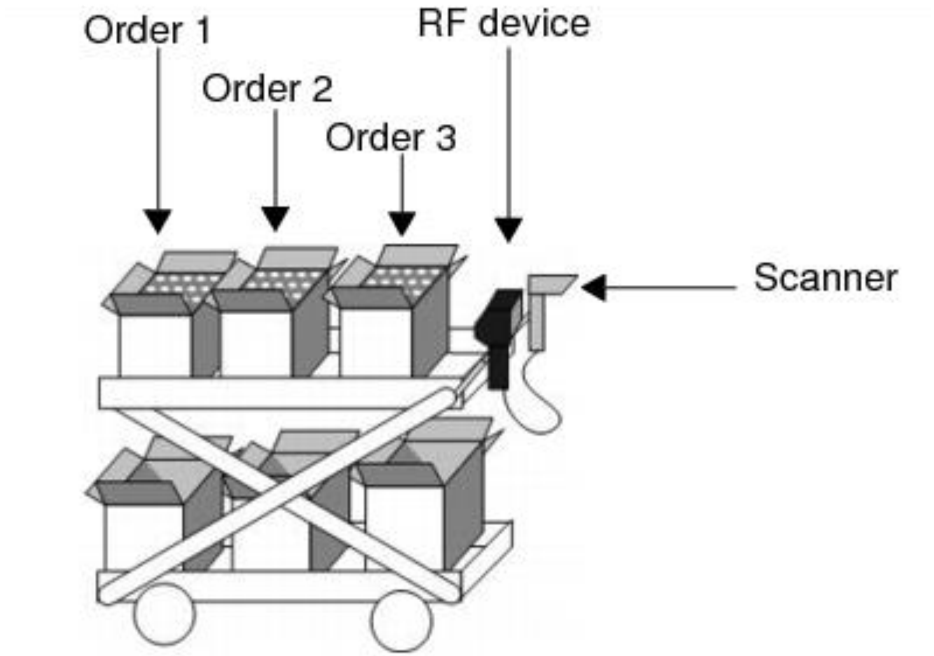
Area picking / U path picking



Pick by label

- Each operator is given a batch of labels detailing location, quantity etc - once all labels are attached to the products and placed in a carton or onto a pallet the individual order pick is complete

Cluster Picking method

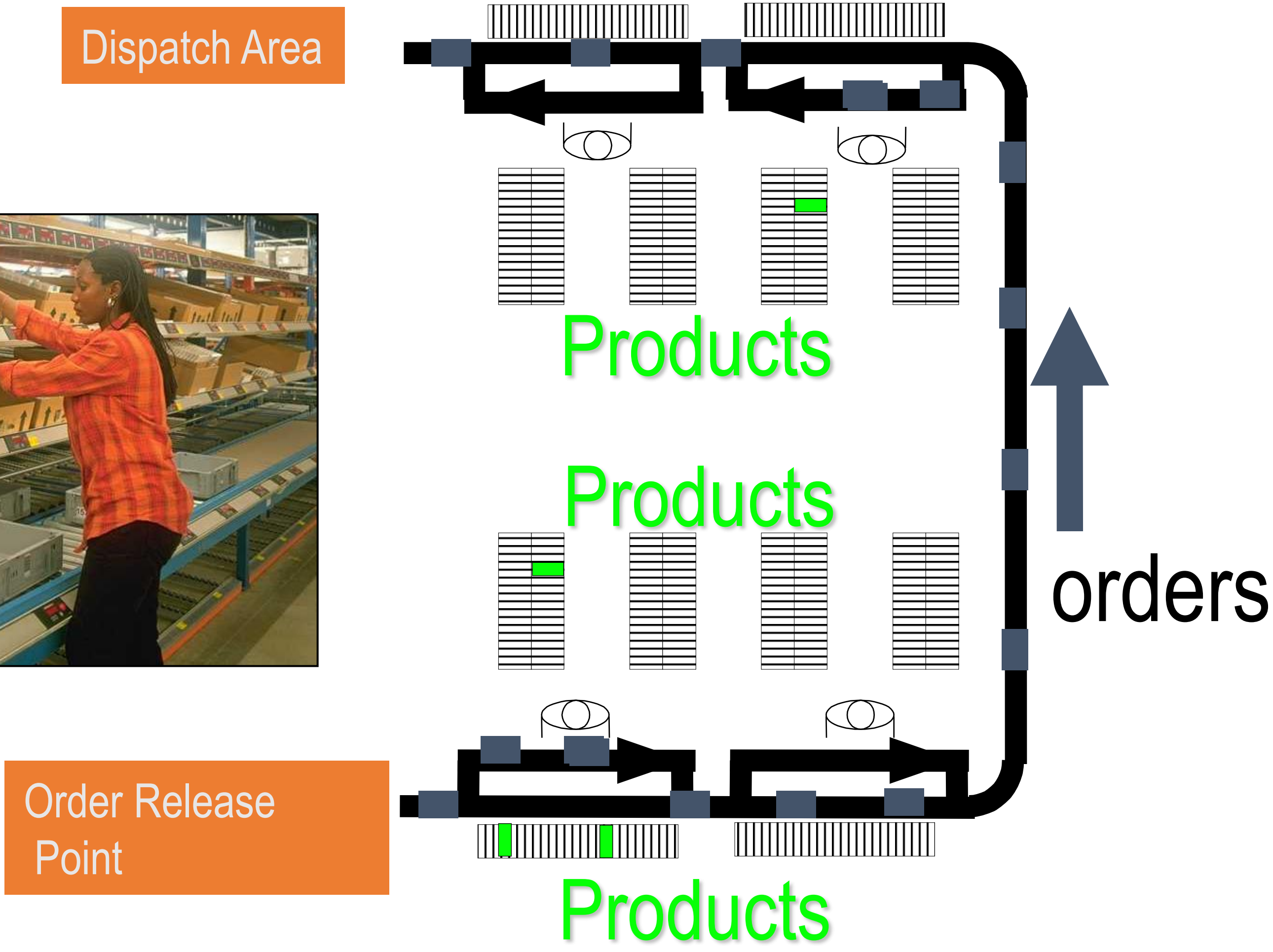


(Photos by QAD, Kardex Remstar)

Zone picking

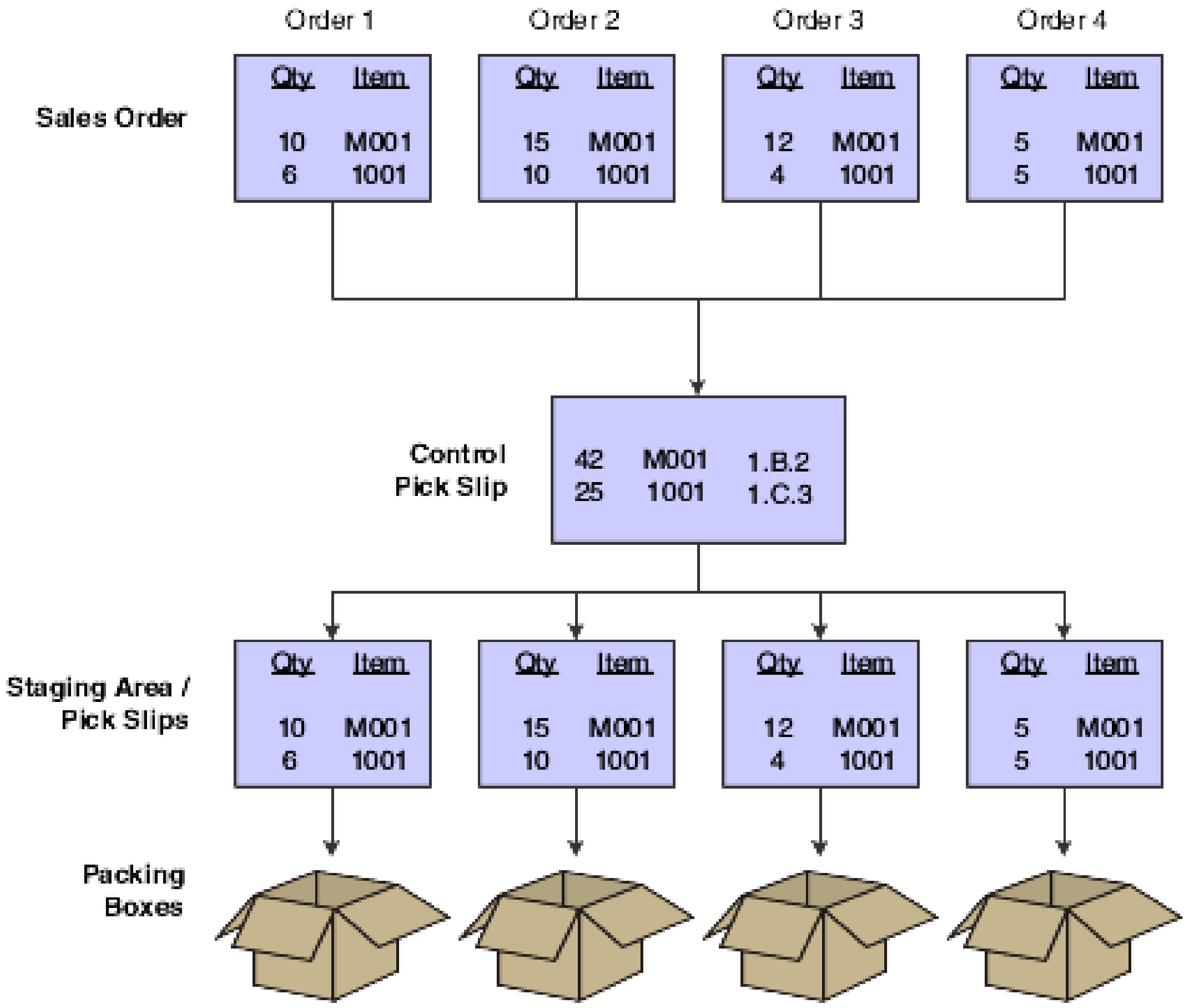
Can be simultaneous or sequential

Each person is allocated their own area



Courtesy of VanDerLande Industries

Batch picking



Oracle.com

Wave picking

- There are two basic planning elements and benefits of wave picking.
- To organize the sequence of orders and assignment to waves, consistent with routing, loading and planned departure times of shipping vehicles or production requirements, etc., to reduce the space required for shipping dock handling to assemble orders and load; and
- To assign staff to each wave and function within a wave, with the expectation that all the work assigned to each wave will be completed within the wave period and thus more effectively utilize the staffing throughout the shift.

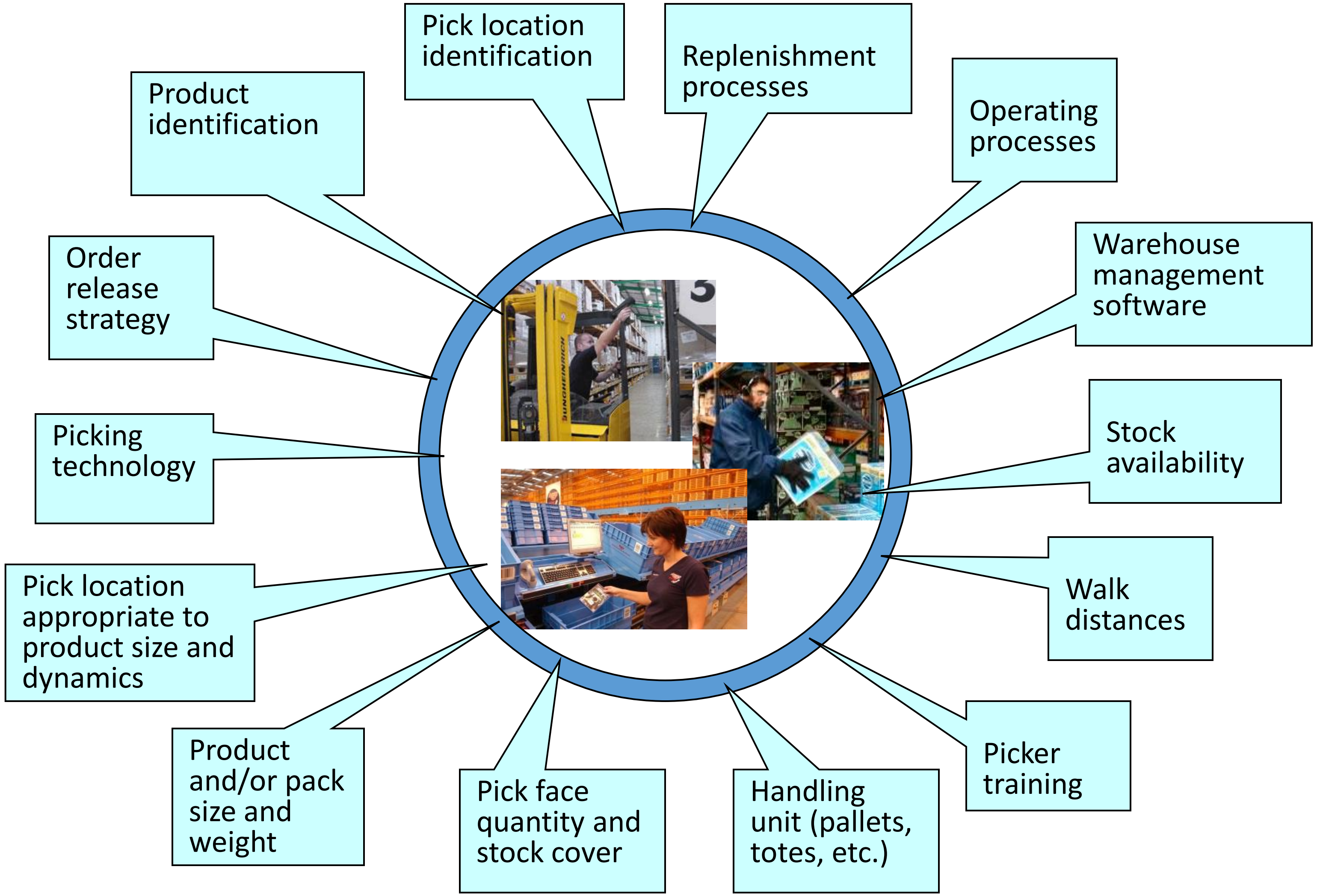
Goods to person

Increased use of automation – goods to person

Order distribution System (ODS) is a dynamic goods-to-person solution. It is especially strong in business processes where a large numbers of order lines are fulfilled from relatively low numbers of articles. Totes or cartons are transported by a conveyor system to operators who place goods into order totes controlled by put-to-light displays.

Courtesy of VanDerLande Industries

What affects picking performance?



Courtesy of The Logistics Business

The human factor

- Safety first
- Ergonomic design of storage system and equipment
- Light loads (max 25 kgs men, 15 kgs women)
- Adequate lighting
- Comfortable temperature
- Clear instructions
- Clear labelling
- Adequate breaks
- Good communication with team
- Good supervision

Replenishment

When using pick or forward locations

- Replenishment is the replacement of goods picked from the forward locations
- Goods are transferred from bulk or reserve locations
- This can be done overnight, at the beginning or end of a shift or during the picking process depending on the urgency – however try not to replenish at the same time as you are picking
- Ensure sufficient items in pick location for duration of shift if possible

- **Biggest error is to have an empty pick location**

Value Adding Services

- Labelling
- Kitting
- Sub-assembly
- Testing
- Packing
- Shrinkwrapping
- Tagging
- Kimballing
- Promotional work (e.g. BOGOF)
- Gift wrapping
- Call centre support

Despatch

- Random quality checks on exit depending on product value
- Pack products securely and safely
- Weigh product as an alternative to physical count
- Recording of batch numbers, serial numbers etc.
- Load manifest compilation
- Loading in sequence
- Load optimisation (e.g. Cubiscan)
- Smooth the flow of despatches
- Vehicle sealed and recorded

Load optimisation

Pallet configuration – no overhang
- Optimum number of cartons

Vehicle load configuration – Optimum number of pallets/cartons

http://onpallet.com/

Packing on despatch

Stretch-wrap machine

Stretch-wrap by hand

Pallet straps (courtesy of Velcro)

Shrink-wrap tunnel
(Courtesy logismarket)

Packing station, (courtesy Cisco Eagle)

Automatic carton erector and sealer

Housekeeping/Supervision

If you have a large warehouse you may have separate teams for the following:

- Provision, allocation and maintenance of equipment
- Replenishment of fast moving items
- Dealing promptly with non-conforming, lost or found stock
- Security of high value or hazardous stock
- Identification of non-moving stock
- Ensuring efficient space utilisation
- Work flow and congestion
- Cleanliness of warehouse
- Review of procedures

Minimising Theft

- Staff training and awareness
- Use of CCTV
- Use of lockable cages or Carousels for high value goods
- Parking of cars away from the warehouse
- Random searches
- Regular cycle counts
- Staff vigilance
    - Especially in dark, less accessible areas of the warehouse. These are prime areas from which product will disappear. Same goes for inventory near exit doors. Staging areas for both incoming and outgoing shipments may be too close to the dock doors. If no one is around to keep an eye out, it would be easy to take something and put it in a truck.
- Conduct security surveys/audits (Independent)
- Use security tags for vehicles leaving the warehouse

Stock counting

- Perpetual inventory or cycle counting
  - Use ABC analysis to determine how many and how often you count which items of stock e.g. 8% of A, 4% of B and 2% of C items
- Monthly, quarterly, annual stock checks
  - Depends on what you agree with your auditors

N.B. You need to be organised:
Who's counting, are they trained and motivated, what are you counting, when do you count, what tools do you need.

Stock turn

- How often stock turns over in a warehouse
- How to calculate:
  - Divide the total throughput of items by the average number of items in stock

  Or
  - Divide the total cost of sales by the total average cost of goods stored at a particular time

Examples of stock turn

100+: Japanese manufacturing company

30-100: Good European manufacturing or distribution

10-30: Typical European manufacturing

10 – 35: Retailer

<10: Poor European manufacturing

<2: Maintenance stores

Stock turn

- The following table provides data regarding sales and average stock holding per month for ACME products.
- Calculate the stock turn.

Month	Sales per month	Average no. of units in stock
January	40,000	150,000
February	32,000	165,000
March	35,000	170,000
April	90,000	175,000
May	100,000	165,000
June	75,000	153,000
July	45,000	126,000
August	32,500	122,000
September	40,000	165,000
October	58,000	185,000
November	74,000	195,000
December	84,000	110,000

Stock turn

Month	Sales per month (units)	Average no. of units in stock (units)
January	40,000	150,000
February	32,000	165,000
March	35,000	170,000
April	90,000	175,000
May	100,000	165,000
June	75,000	153,000
July	45,000	126,000
August	32,500	122,000
September	40,000	165,000
October	58,000	185,000
November	74,000	195,000
December	84,000	110,000
	705,500	156,750
Stock turn = 4.5		

Days stock in hand

Item ID	Description	Tot QOH	M1-12 Usage	Days stock	Year's stock
SE041-002-02R	BOTTLE REPLACEMENT SALINE STA	39	1	14235.0	39.0
HN031-020-01	CAP .375 IN NPT SST	77	3	9368.3	25.7
ZN80	CASSETTE 9X12	24	1	8760.0	24.0
EC211-001-01	CONNECTOR F TYPE CRIMP-ON	96	4	8760.0	24.0
0285263	BOOTLACE FERRULE 1.5 SQ MM WIRE INSULATED BLACK PK 100	92	4	8395.0	23.0
MF551-S11-13	ALL THREAD .25-20UNC-2A X 1 316SS	64	3	7786.7	21.3
MB041-011-01	SEAL SHAFT RING CURVETECH	20	1	7300.0	20.0
0218293	FERRULE 90 SERIES -4 SST	19	1	6935.0	19.0
EC121-033-01	CONNECTOR CIRCULAR STRAIGHT PLUG 6 PIN MALE	16	1	5840.0	16.0
0378818	CAPACITOR ALUM ELECTROLYTIC 100UF 35VDC RADIAL 8MM DIA	47	3	5718.3	15.7
0415982	HOSE SUCTION 1-1/4 IN W/ FEMALE JIC STR ENDS SPEL-6000 TMS	15	1	5475.0	15.0
AC99-R	CLEANER (AEROSOL)ARDROX 9PR5	30	2	5475.0	15.0
AD99-R	DEVELOPER (AEROSOL)ARDROX 9D1B	28	2	5110.0	14.0
HN071-078-01	ELBOW .75 NPTF 90 DEG SST	25	2	4562.5	12.5
0009398	HEAT SHRINK SLEEVING BLK 3IN DIA ADHESIVE WALL	12	1	4380.0	12.0
0314786	KIT FIRST AID 50 PERSON	12	1	4380.0	12.0
BPGA	GRIGRI	12	1	4380.0	12.0
0206719	LIFT TUBE MOUNT AFT	35	3	4258.3	11.7
0318915	COUNTERSINK SLTD FLT LG 90 DEG M2.5 - 0.45 X 10MM	23	2	4197.5	11.5
0270423	TUBE STABBING GUIDE CAGE EXTENSION DETAIL	11	1	4015.0	11.0
CA121-002-02	TAPE DUCT OLIVE DRAB 2.83 IN WIDE X 60 YD LONG	21	2	3832.5	10.5
IX01-0005AB	AGFA RCF SCREENS 70mm x 5mtr	21	2	3832.5	10.5
MM021-523-01	O-RING,8.10 ID X .070 BUNA 70 004-0792	21	2	3832.5	10.5
AD02-R	DEVELOPER MANUAL G128 2QBUS	10	1	3650.0	10.0
0006659	CONNECTOR BNC PLUG RG179 75 OHM MINIMUM	20	2	3650.0	10.0
MB011-N22-79	O-RING 2-279 BUNA N70	20	2	3650.0	10.0

Average Days of Sales held in inventory- USA by REL

Top 5 lowest DIO (Days inventory outstanding) sectors:

(1) Retail Convenience Stores: 8.4;
(2) Restaurants: 12.6,
(3) Business Furniture 19.3;
(4) Retail Grocery: 30.1;
(5) Printing: 30.2

Top 5 highest:

(1) Spirits: 287.6;
(2) Retail Auto Parts: 208.9;
(3) Pharma: 177;
(4) Biotech: 161.2;
(5) Life Sciences Equipment: 151.1

Other notable sectors:

Food Manufacturing:59.5
Chemicals and Gases: 76.8
Apparel and Shoe Manufacturing: 112.2
Mass Merchants and Dept. Stores: 78.6
Consumer Packaged Goods: 64.6
Computers and Peripherals: 41.7

Average Inventory Level/[total revenue*365]

Warehouse Automation and Equipment

Section 6

Warehouse automation and technology

Support systems	Semi-automation	Automated systems
Warehouse Management systems	Carousels/Vertical lift modules	AS/RS (Automated storage and retrieval systems)
Warehouse Control Systems	A frames	Cranes
		Shuttle systems
Bar codes and scanners	Pick and put to light	Conveyors
Radio frequency ID	Shuttle carts	Automated guided vehicles
Scanners and voice terminals		Robotics

Warehouse automation
Case study – Tele Danmark site

Introduction of very narrow aisle mini-load crane system.

Consolidated stock from 3 distribution centres and 60 small local sites into a Single warehouse of 7,200 square metres. This handling system supported 13,500 lines and an annual throughput of 7,000,000 items.

Other benefits included:-

- Handling costs reduced by 75%
- Order accuracy improved from 62% to 96%
- Duplicate stock was almost eliminated
- Flexibility improved – same day order despatches
- Reduced labour costs

Warehouse of the month – Modern Materials Handling Online

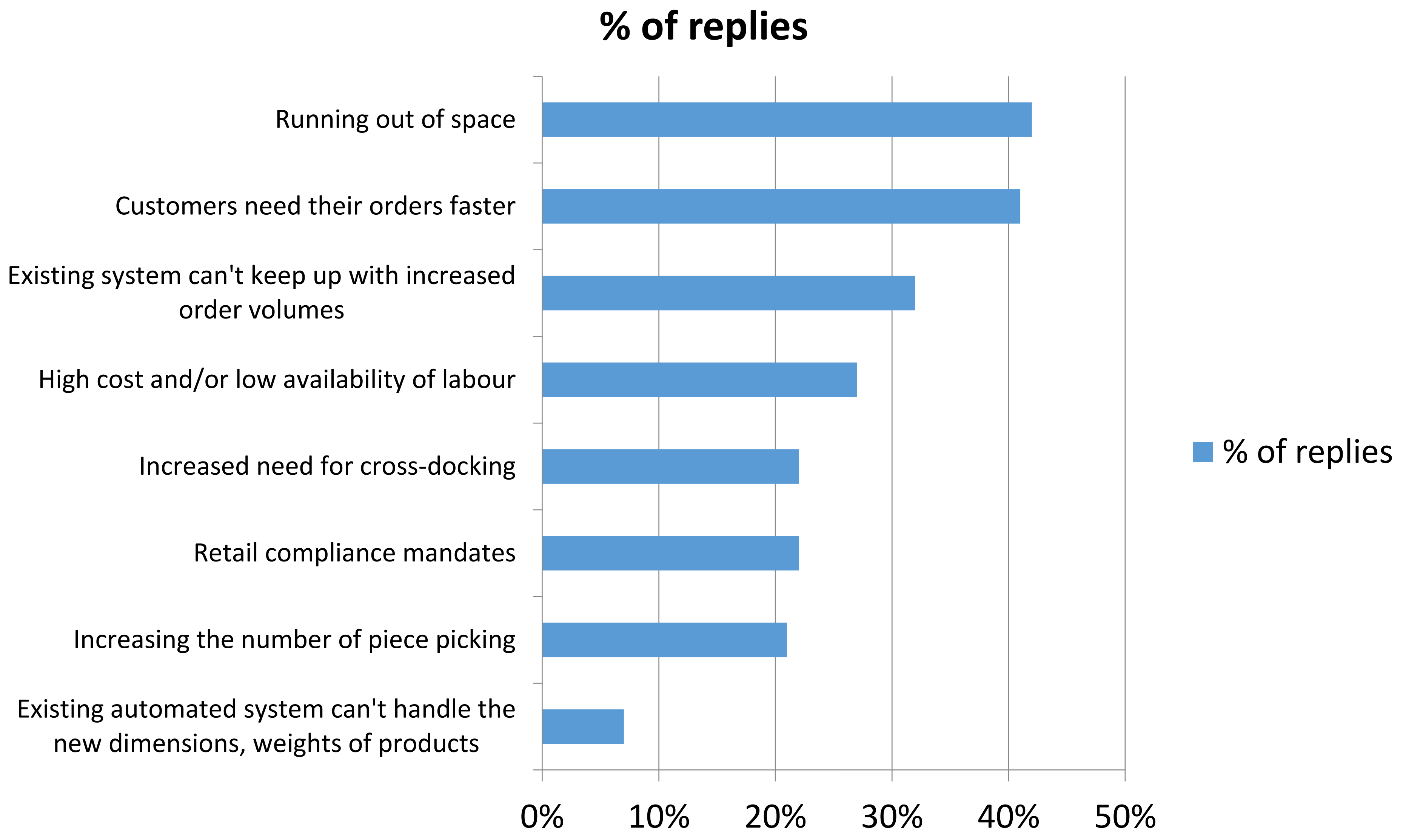
Advantages of Automated systems

- Increased Space Utilisation
    - High bay narrow aisle systems (up to 30 metres high)
    - Random storage
- Improved Control
    - Pallet tracking through enhanced warehouse management system
- Labour and Energy Savings
    - No heat and light requirement apart from maintenance
    - Minimum supervision required
- Continuity
    - 24 hour, 7 days per week operation
- Product Security
    - High bay areas, Use of First in First out principles, less human intervention
- Safety
    - Elimination of majority of manual handling
    - Reduction in accidents
    - Can cope with hazardous/harsh environments
- Integration
    - Coordination of product flows, avoiding bottle necks
    - Constant performance levels
    - Continuous review

Disadvantages of Automated systems

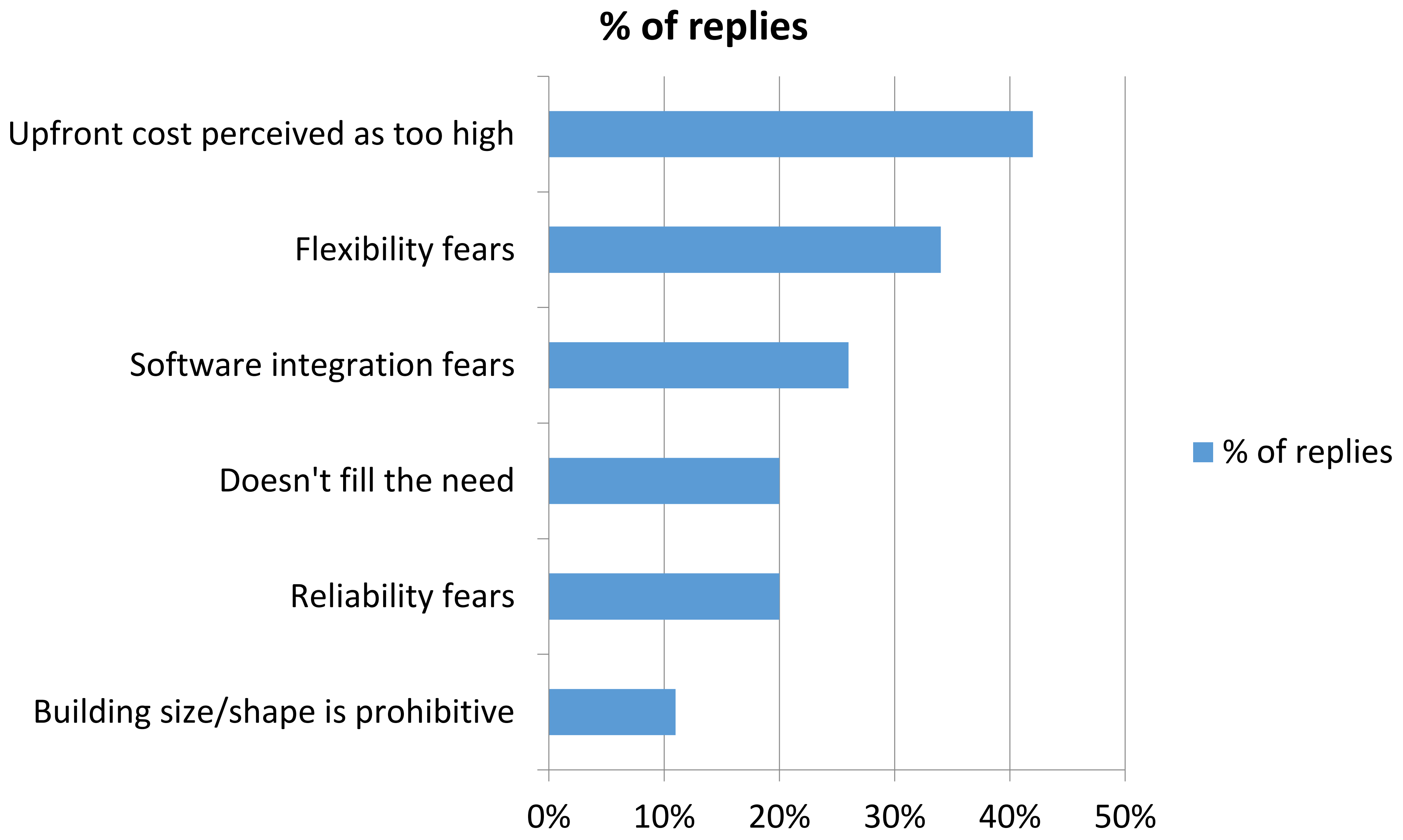
- High investment costs
  - Building, equipment, Information technology
- System failure, operations are entirely reliant on technology
- High opportunity cost
- Require standardised unit loads
  - Anomalies not accepted and need to be handled separately
- More quality control required at inbound
- High cost of disposal of equipment
- Lack of flexibility

Reasons for choosing Automation



Aberdeen Group

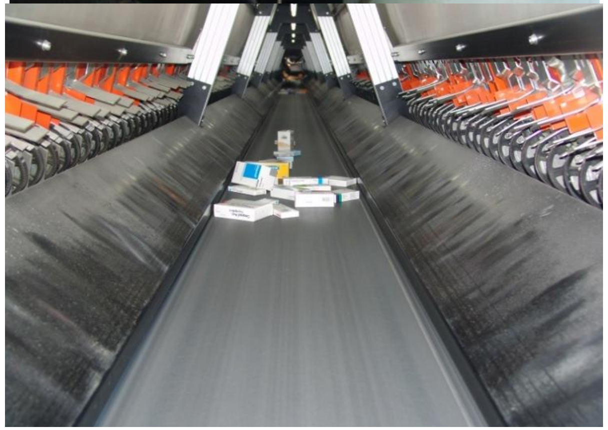
Reasons against automating a warehouse



Aberdeen Group

Automated guided vehicle

A Frame – automatic pick



Courtesy of Knapp and SSI Schaeffer

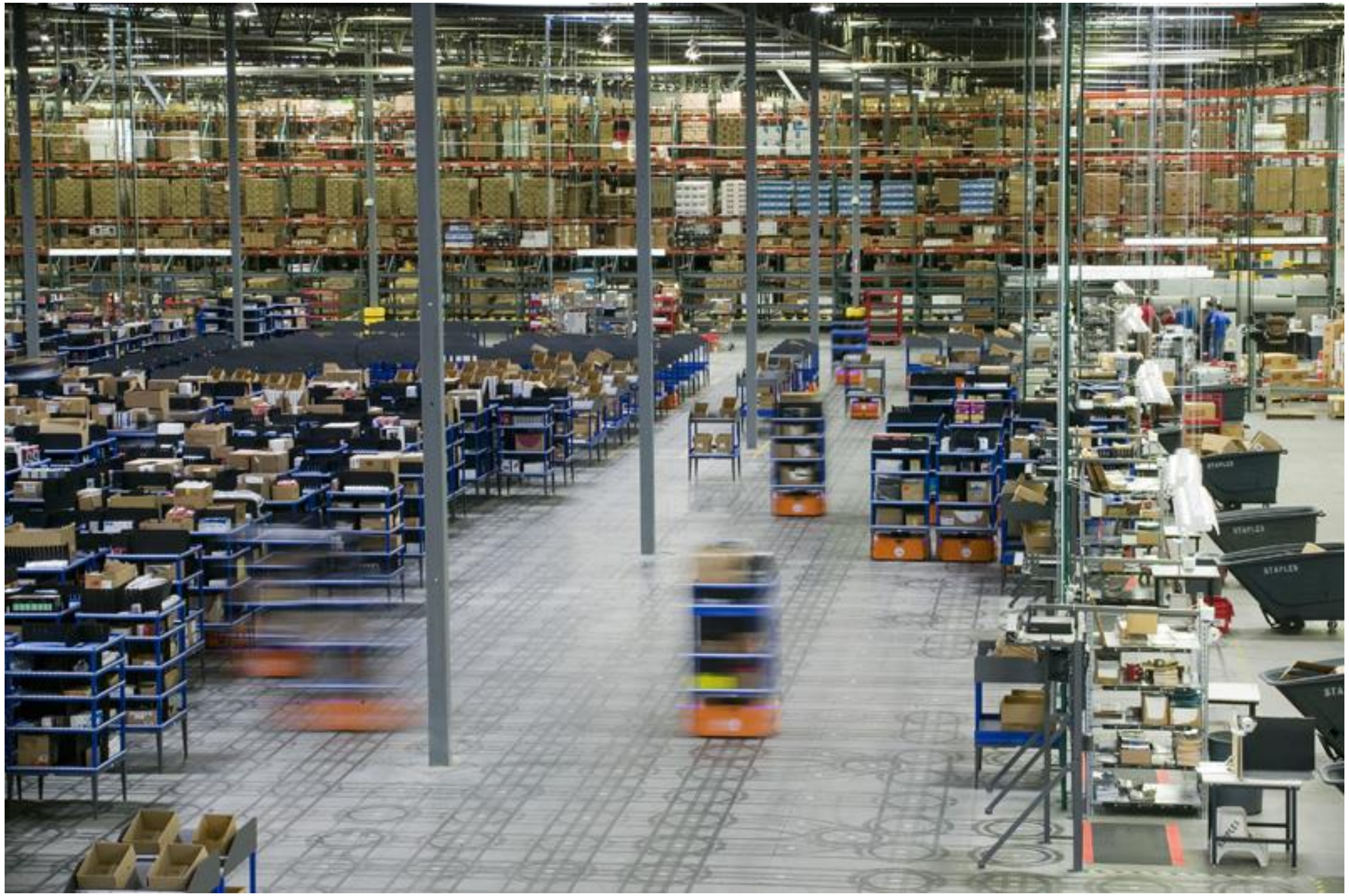
Other automation systems

- Cimcorp 3D shuttle
- No racks

More automation

- Swisslog Autostore

Robo pick by Kiva



10,000 sq. metres - $4 - $6 million

Automation in pallet storage

- Proctor and Gamble – Activ pallet sequencer

  by Retrotech

Storage Systems

Section 7

Main types of storage systems

- Block stacking
- Wide aisle racking
- Cantilever racking
- Narrow aisle racking
  - Automated
  - Manual
- Drive-through/ Drive-in racking
- Sliding or Mobile racking
- Double deep racking
- Push-back racking
- Flow or Live racking
- Mezzanine
- Carousels

Storage Equipment

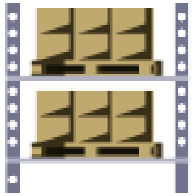
Bulk Storage/Block Stack

- High density storage on the warehouse floor.
- Unit loads stacked on top of each other
- Best for large quantities of a single SKU (stock keeping unit)
- Allowable stack heights (3 or 4)
- Low utilization threshold

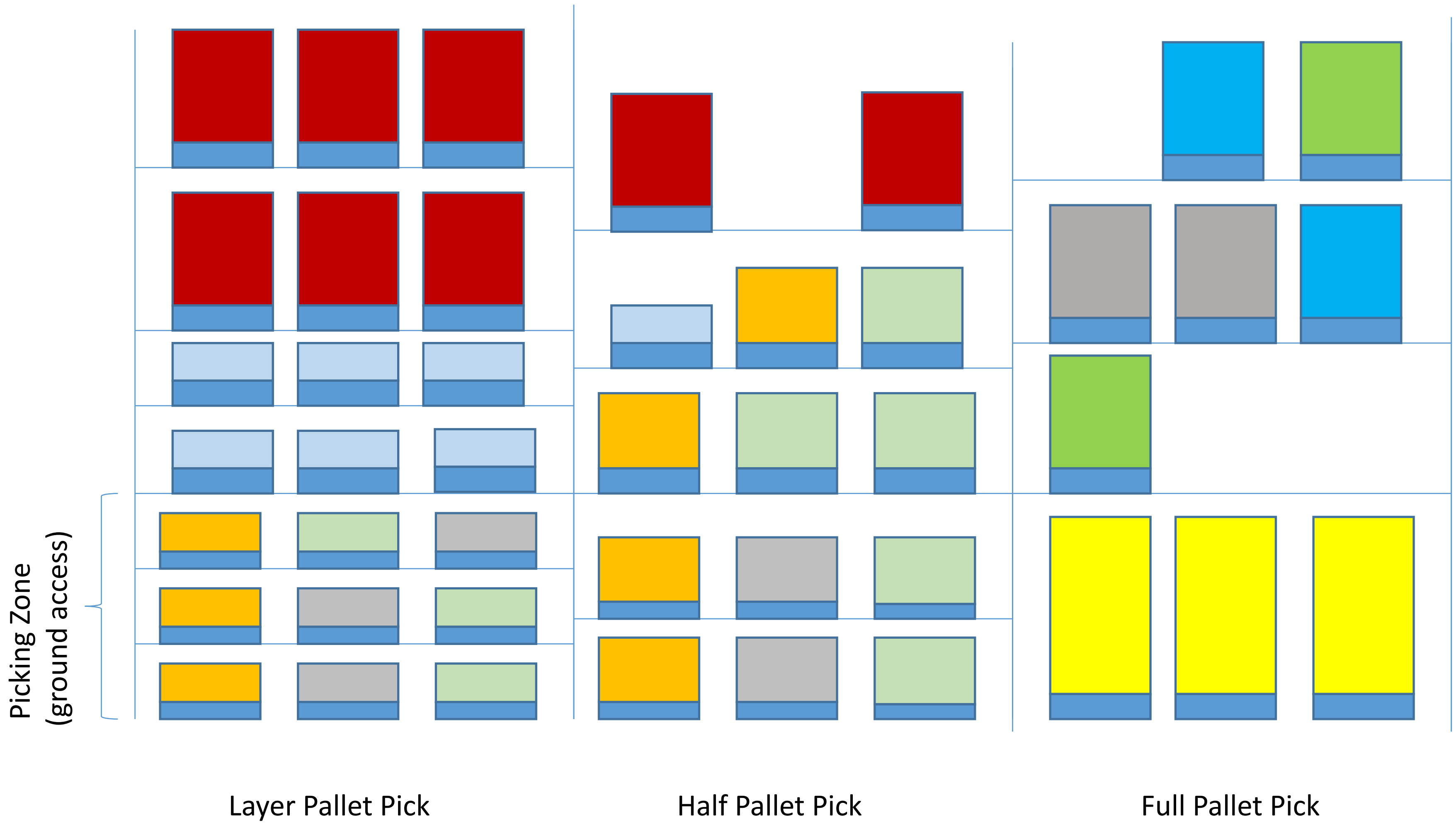
Storage Equipment

Adjustable Pallet Rack APR

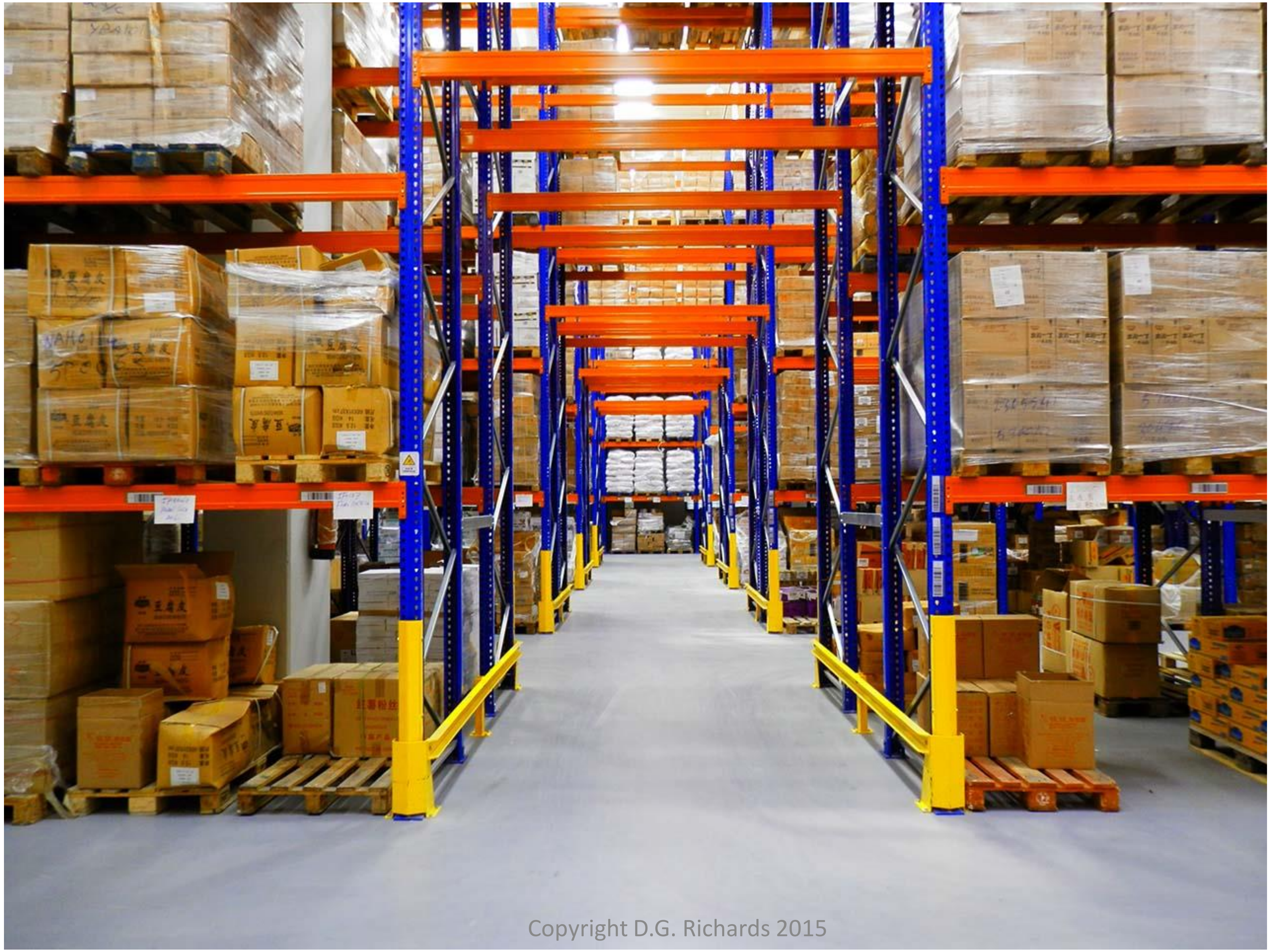
- Consists of uprights, beams and back supports
- Anchored to floor with adjustable beams
- Must know weight capacity, width of rack opening and the distance between load bearing beams
- Flexible and easily reconfigurable



Rack configuration options



Rack tunnels



Storage Equipment

Cantilever Rack

- Storage of long materials such as piping or wood products
- High capital cost per square foot
- Higher density for multiple SKU's

Warehouse storage methods

Very Narrow aisle racking

- Consists of uprights, beams and back supports
- Anchored to floor with adjustable beams
- Requires less space than APR
- Must know weight capacity, width of rack opening and the distance between load bearing beams

Storage Equipment

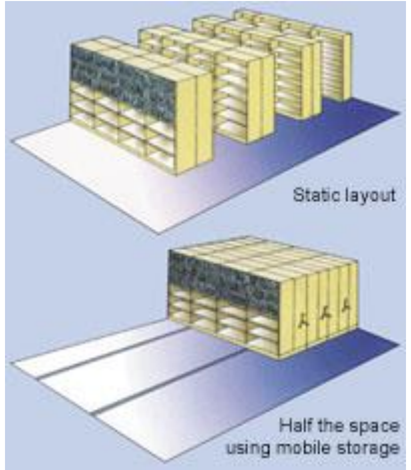
Drive-in/Drive Through Rack

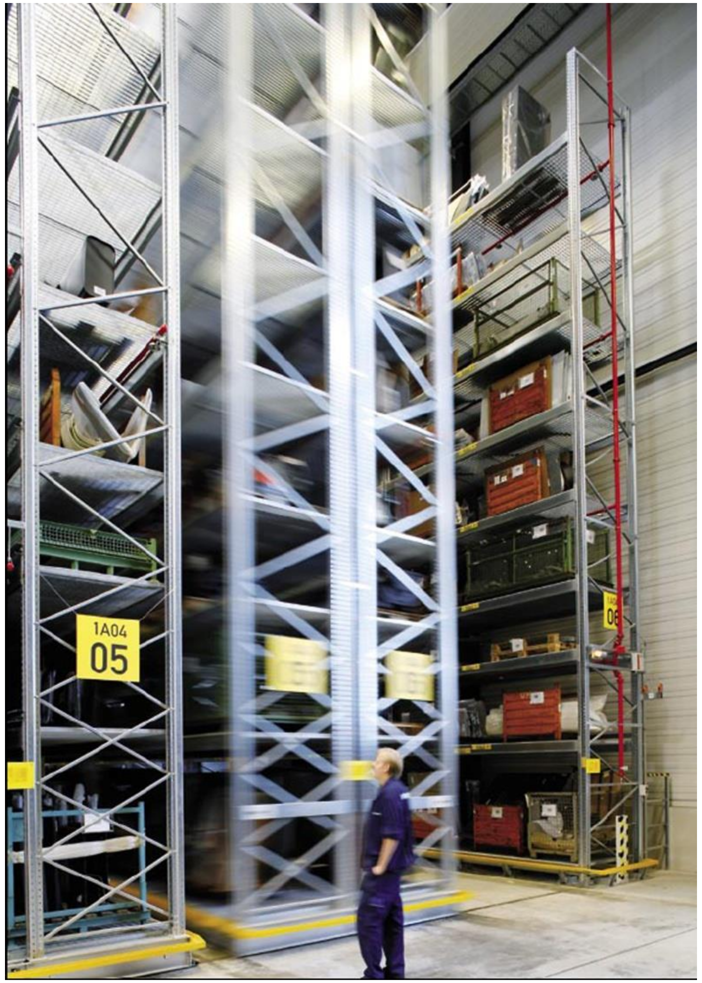
- Similar to pallet racking but the forklift can drive into the rack
- High density storage medium for large quantities of single SKUs
- Need good quality pallets
- LIFO - Drive In
- FIFO - Drive Out

Storage Equipment

Sliding Rack or Shelving

- Mounted on guides or rails
- Highly space efficient
- Very effective for small parts and high SKU
- Strong medium for slow moving parts





Storage Equipment

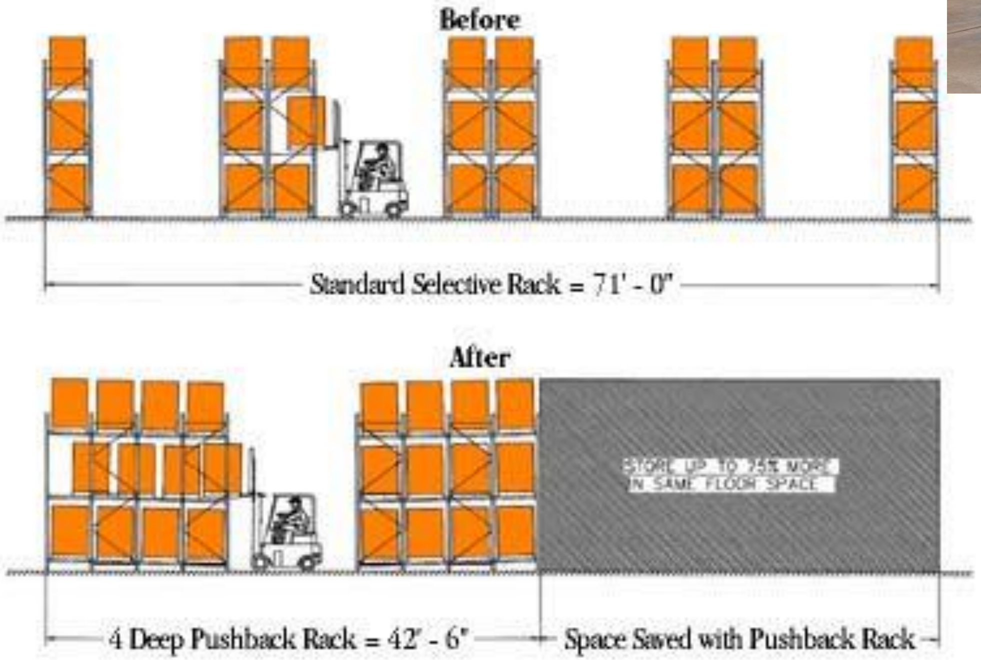
Double Deep Rack

- High Density Storage medium
- Must use reach truck only with extendable forks
- Requires multiple pallets of Single SKUs

Storage Equipment

Push back racking

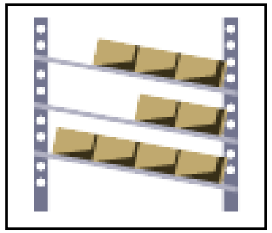
- Supports slow moving product
- Needs same product in the line
- LIFO
- No individual pallet access



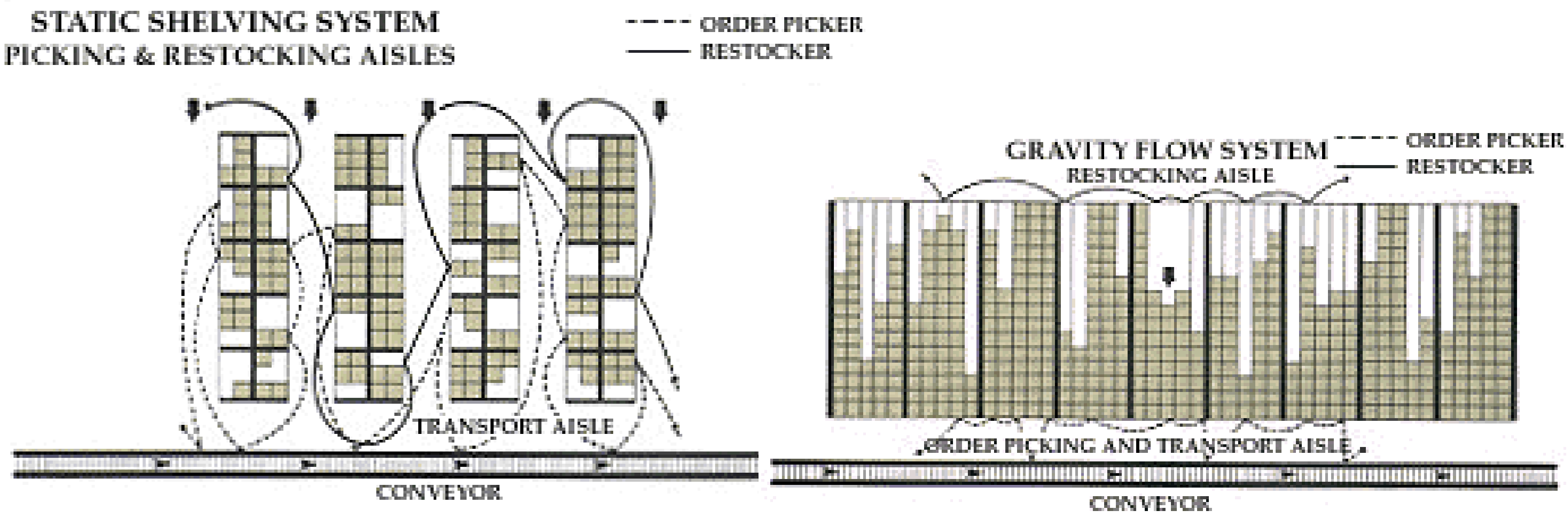
Storage Equipment

Flow or Live Rack

- Great for carton flow or piece pick
- Many SKU's in small footprint
- Supports high speed and slow moving product
- Designed for High speed picking



Gravity flow versus static shelving

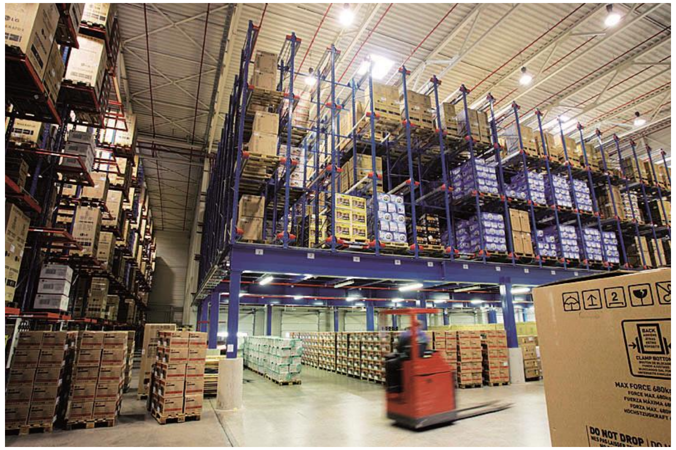


Courtesy of Cisco Eagle

Storage Equipment

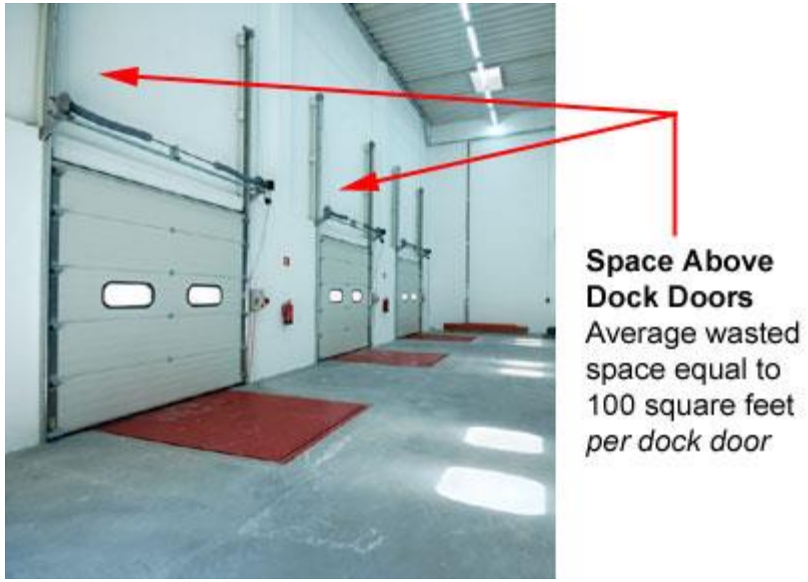
Satellite/Shuttle racking

- No aisles
- Many pallets in small footprint
- Supports high speed and slow moving product
- Good utilisation of space at the loading bay
- Continuous flow



Capacity utilisation

- Warehouse managers are tasked with making use of the whole cubic volume of the warehouse taking into account accessibility, practical utilisation limits, cost and accountability
- Consider introduction of mezzanine floors for example – e.g. space above dock doors

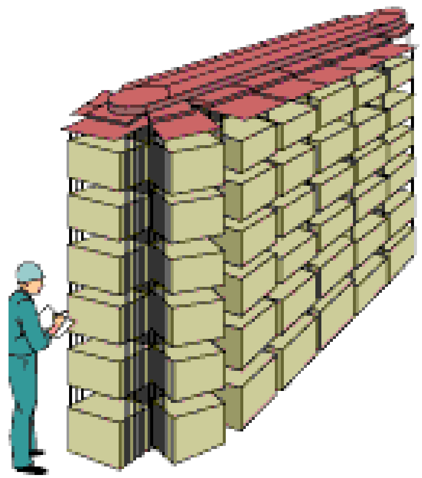


Courtesy of AWS Ltd and Cisco Eagle

Storage Equipment

Horizontal and vertical Carousel

- High capacity storage for pick and pack
- Brings parts to operator
- High speed picking solution, reduction of travel by SKU
- High security
- Good ergonomics



Decision table

	Wide aisle	Narrow aisle	VNA	Drive in	Double deep	Live storage	Mobile racking
Floor space utilisation	2	3	4	5	3	4.5	4.5
Cubic space utilisation	3	4	5	3.5	4	3.5	4
Access to each pallet load	5	5	5	1	3	4	3.5
Speed of access	4	3	3	2.5	3	5	2
Stock rotation	4	4	4	1	3	5	3
Stock control and mgt.	4	4	4	2	2	5	3
Specialised mhe (in terms of cost)	No 5	Yes 2	Yes 1	No 5	Yes 3	No 5	No 4
Ease of re-location	5	4	2	3	3	1	1
Speed of installation	5	4	2	3	4	3	1
Beam adjustments	5	4	1	1	2	1	3
Total	42	37	31	27	30	37	29

Advantages/disadvantages – marks out of 5

Mechanical Handling Equipment

Section 8

Choice of pallet movers

- Functions to be performed
- Type of product
- Degree of use – shift length, work patterns, pallets per shift, seasonality, peaks and troughs, special handling requirements
- Travel distances and lift height, inside and/or outside the warehouse, private/public roads, working conditions (freezer, chill, ambient, hazardous).
- Type of fuel, diesel, LPG, Electric. Available ventilation, noise level, space for re-charging and storing batteries
- Store layout and dimensions
- Building restraints
- Floor condition
- Aisle gangway space at front and between racks – can the truck turn 90 degrees. Also needs additional 200mm to its normal turning circle
- Delivery and collection vehicles
- Access doors, bays, overhead pipes (sprinklers)
- Rack heights
- Method of acquisition and maintenance
- Budget

A variety of trucks to choose from

Courtesy of Toyota

Vertical movement






(Courtesy of Atlet, Toyota, Central Training and Flexi),

Horizontal movement

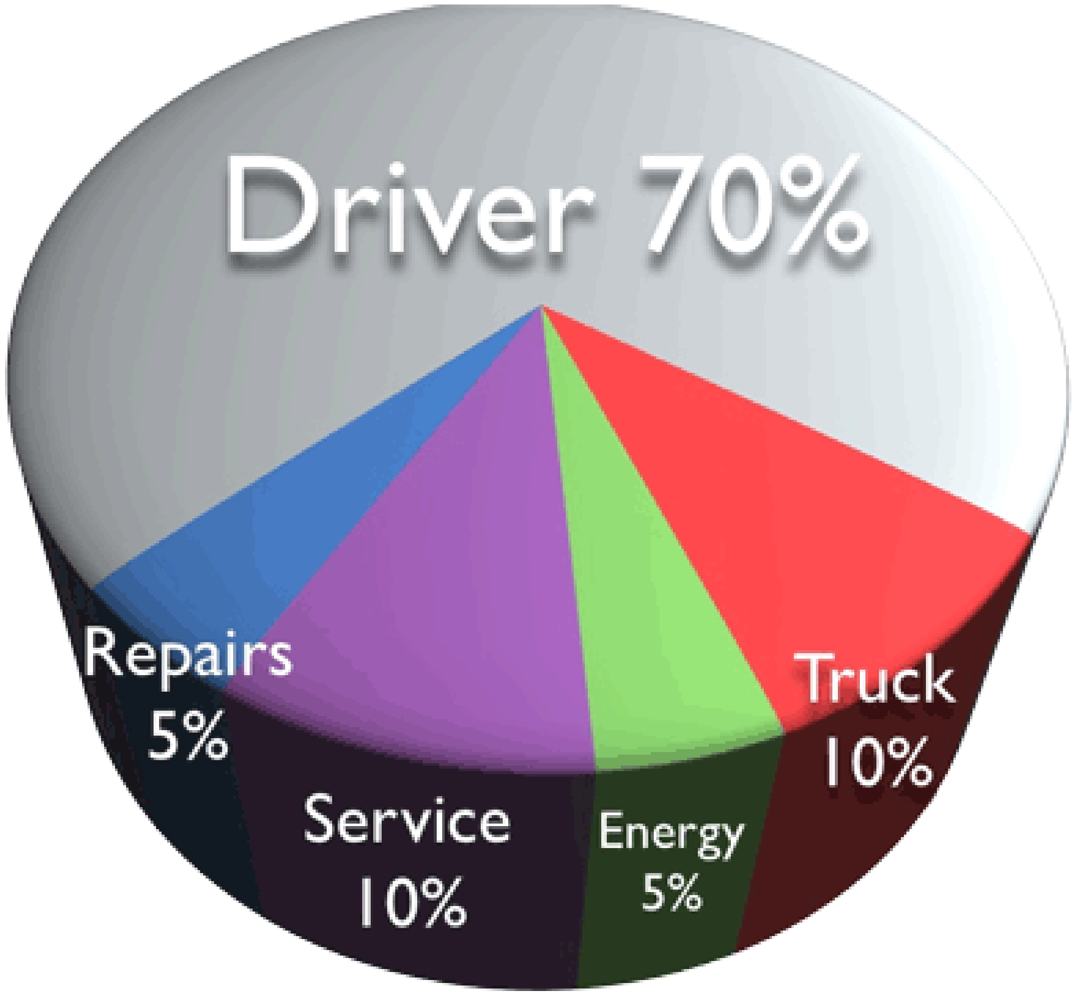
Courtesy of Demag, AS Conveyor Systems and Seegrid),

Pallet movers

Product type	Lift height	Aisle width (m) Approx.	Lift capacity in kg from	To	Cost from (£)	To (£)
Hand pallet truck, jack	N/A	1.8 m	2,300 kg	3,000 kg	300	1,000
Powered pallet truck	N/A	2.8 m	1,200	3,000	2,800	16,000
Powered pallet stacker	1.35–6.3 m	2.2–3.0 m	1,000	1,600	5,000	18,000
Reach truck	4.5–12.5 m	2.65–3.15 m	1,400	2,500	15,000	30,000
Counter-balance truck	3.0–6.5 m	3.0–7.0 m	1,300	5,000	12,000	20,000
Low-level order picker	N/A	1.636 m	1,800	2,500	7,000	12,000
Medium-level order picker	2.0–4.7 m	1.59 m	1,000	1,200	10,000	18,000
High-level order picker	4.7–9.5 m	1.664 m	1,000	1,200	19,000	32,000
Combination truck or VNA	14.8 m	1.6–2.3 m	1,000	1,500	40,000	80,000
Articulated forklift truck	Up to 12 m	1.6–2.1 m	1,000	2,000	29,000	35,000

Prices and data at July 2013 UK only

Lifetime Costs of MHE Equipment



The pie chart shows the breakdown of the cost of ownership.
Courtesy of Toyota

Warehouse Storage Justification

Setting the scene…

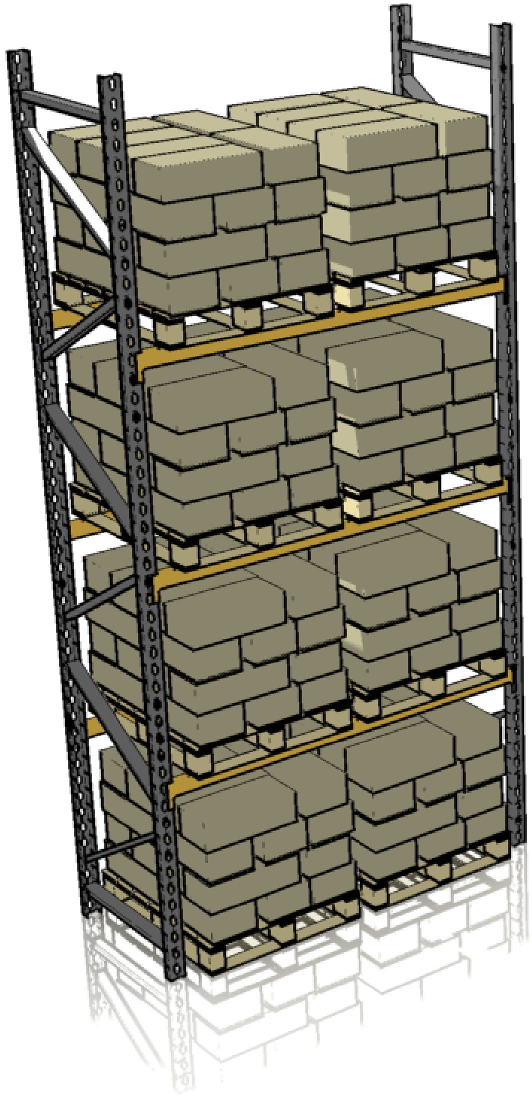
Looking for a new warehouse with 2500 pallet locations…

Warehouse Storage Justification

- **Counterbalance Forklift Truck**
  - Gas/Diesel
  - LPG
  - Battery electric

The Conventional Way

Warehouse Storage Justification



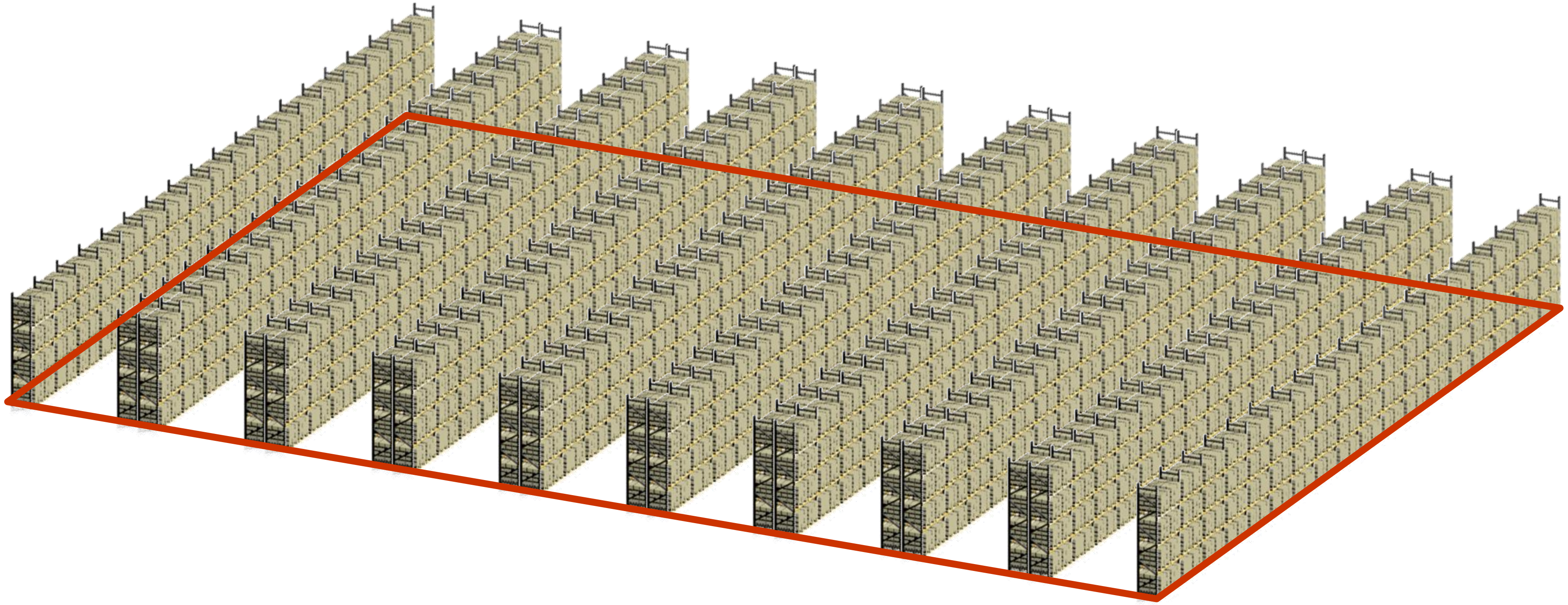
- **Racking system**
  - Clear aisle of 4200 mm
  - Top beam of 4775 mm
  - Stacking 4-high
    - 1 ground location plus 3 elevated beam levels

Warehouse Storage Justification

CONVENTIONAL SYSTEM	NARROW AISLE SYSTEM	VERY NARROW AISLE SYSTEM
Gas, LPG or Electric Trucks		
Clear aisle 4200mm		
Top beam 4775mm		
Stack 4 high (1 on the ground; 3 in the air)		
Single command system		
The truck loads & unloads trailers, loads & unloads rack plus pick up & deliver to manufacturing		
80% Travel. 20% Lift		
66% Aisle		

Warehouse Storage Justification

The Conventional Way - Layout



- **Rack footprint: 3251 sq. metres**

Warehouse Storage Justification

- **Electric Reach Truck**
  - Battery electric
  - Compact frame and reach forks/mast provide for a smaller aisle.

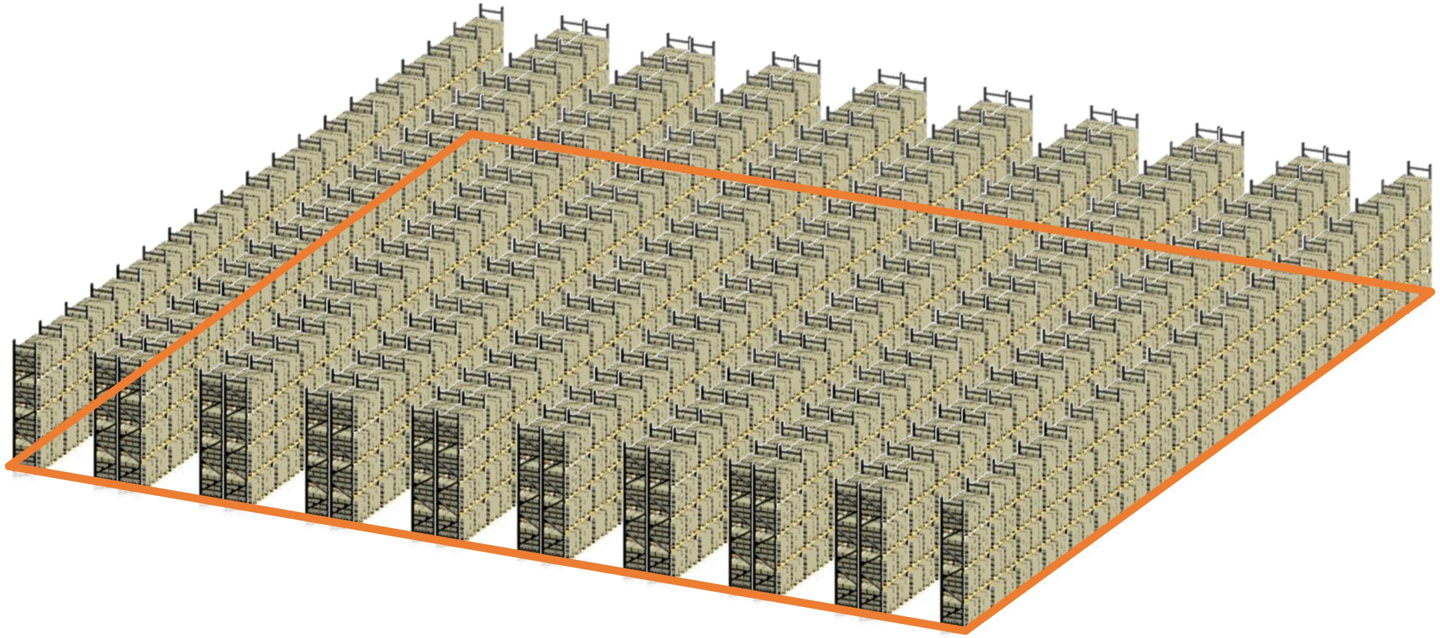
Narrow-Aisle System

Warehouse Storage Justification

CONVENTIONAL SYSTEM	NARROW AISE SYSTEM	VERY NARROW AISLE SYSTEM
Gas, LPG or Electric Trucks	Electric Reach Trucks	
Clear aisle 4200mm	Clear aisle **2700mm**	
Top beam 4775mm	Top beam 4775mm	
Stack 4 high (1 on the ground; 3 in the air)	Stack 4 high (1 on the ground; 3 in the air)	
Single command system	**Dual** command system	
The truck loads & unloads trailers, loads & unloads rack plus pick up & deliver to manufacturing	The truck pick up & deposits loads from staging and pick & deposits loads in the rack systems	
80% Travel. **20%** Lift	**60%** Travel. **40%** Lift	
66% Aisle	**51%** Aisle	

Warehouse Storage Justification

Narrow-Aisle System - Layout

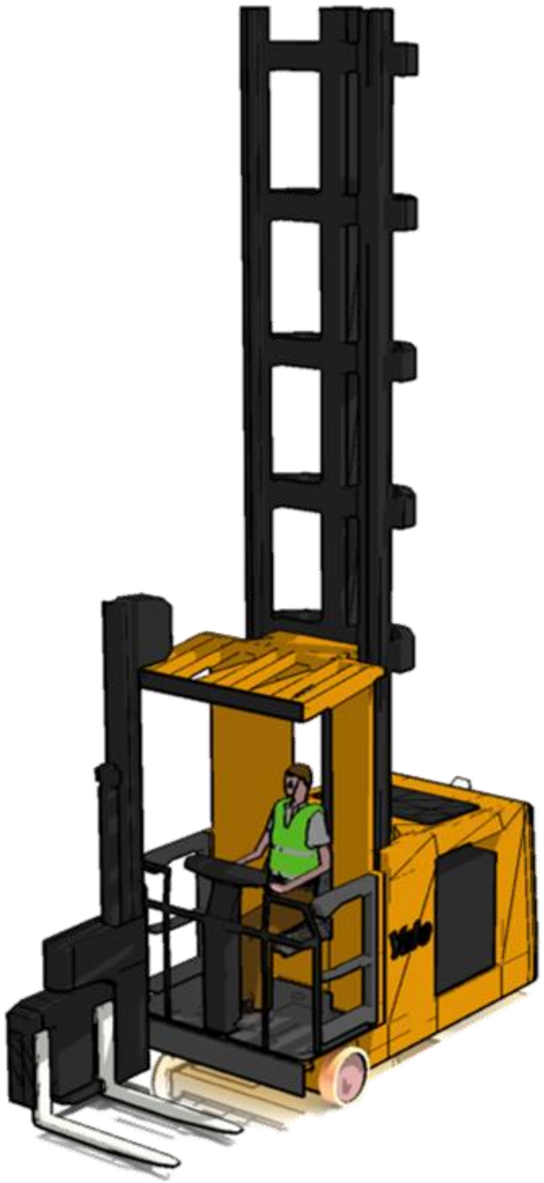


- **Rack footprint: 2554 sq. metres**

Warehouse Storage Justification

- **Electric Very-Narrow-Aisle (VNA) Truck**
  - Battery electric
  - Lateral fork movement allows specification of aisles a fraction larger than the size of pallet.

Very-Narrow-Aisle System



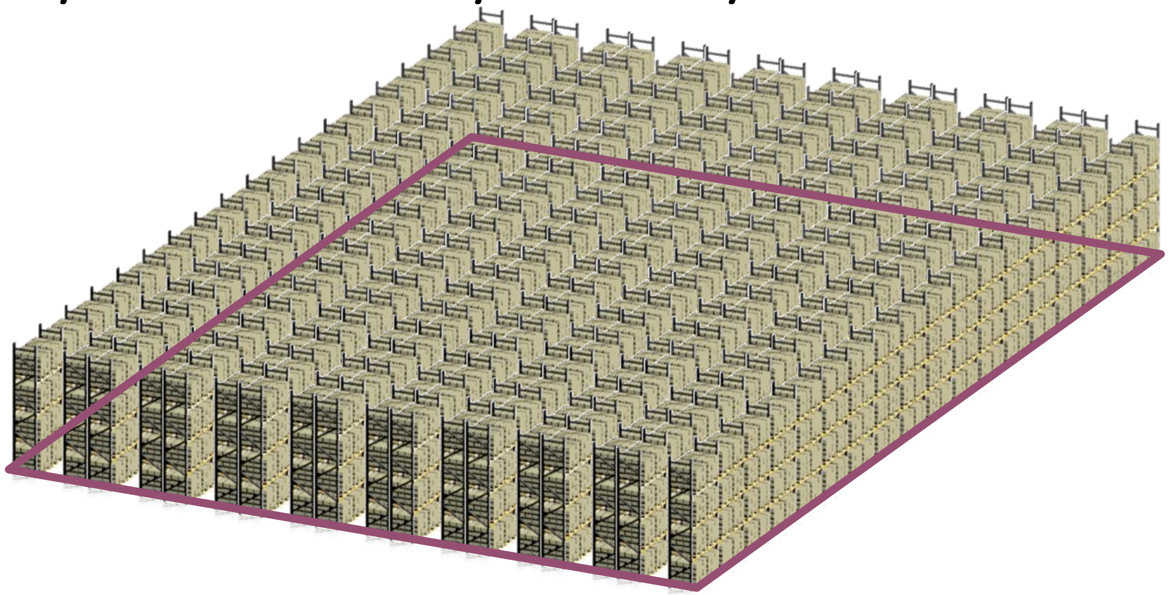
Warehouse Storage Justification

CONVENTIONAL SYSTEM	NARROW AISLE SYSTEM	VERY NARROW AISLE SYSTEM
Gas, LPG or Electric Trucks	Electric Reach Trucks	Electric Very Narrow Aisle Trucks
Clear aisle 4200mm	Clear aisle 2700mm	Clear aisle **1650mm**
Top beam 4775mm	Top beam 4775mm	Top beam 4775mm
Stack 4 high (1 on the ground; 3 in the air)	Stack 4 high (1 on the ground; 3 in the air)	Stack 4 high (1 on the ground; 3 in the air)
Single command system	Dual command system	**Dual** command system
The truck loads & unloads trailers, loads & unloads rack plus pick up & deliver to manufacturing	The truck pick up & deposits loads from staging and pick & deposits loads in the rack systems	The truck pick up & deposits loads from staging and pick & deposits loads in the rack systems
80% Travel. **20%** Lift	**60%** Travel. **40%** Lift	**50%** Travel. **50%** Lift†
66% Aisle	**51%** Aisle	**39%** Aisle

† Travel & Lift are simultaneous

Warehouse Storage Justification

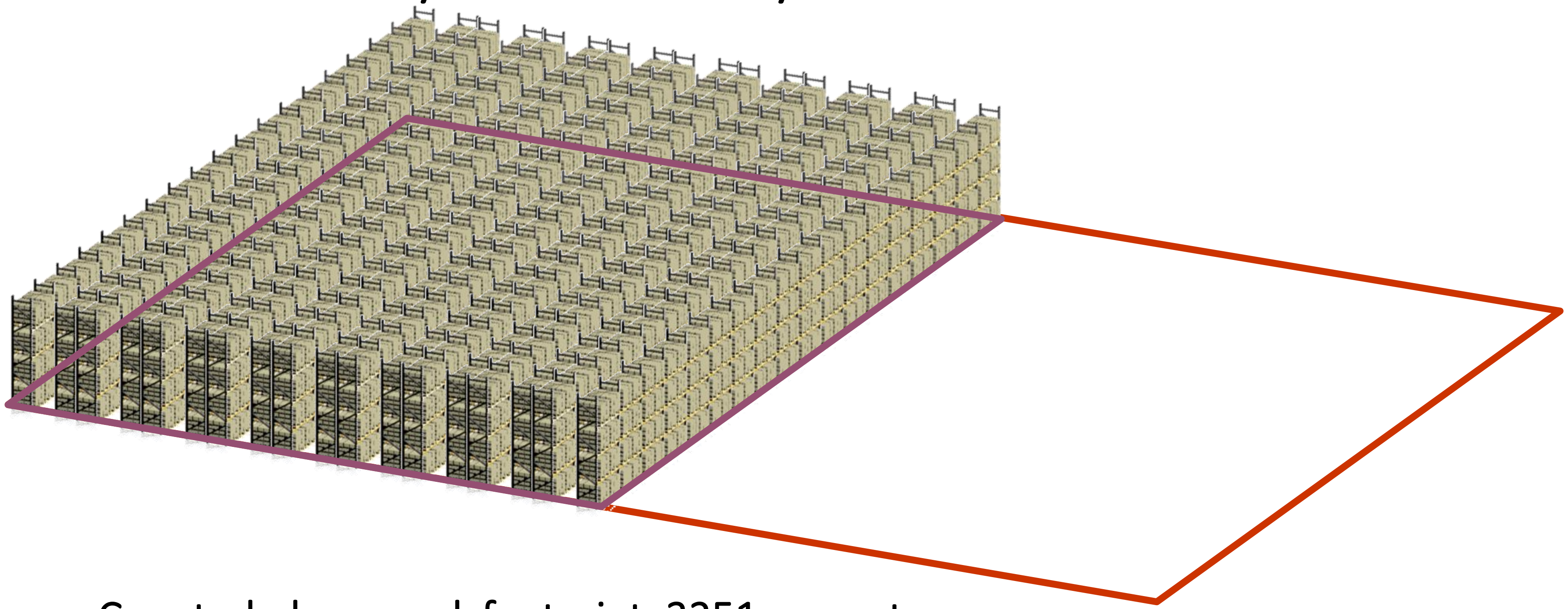
Very-Narrow-Aisle System - Layout



- **Rack footprint: 1950 sq. metres**

Warehouse Storage Justification

Conventional vs. Very-Narrow-Aisle System



- Counterbalance rack footprint: 3251 sq. metres
- VNA Rack footprint: 1950 sq. metres
  - 3251 sq. m - 1950 sq. m = 1301 sq. m (40%)

Special equipment - Slip sheet attachment

Courtesy of Bridgestone

Courtesy of Bluewater Forklift

Courtesy of easy rack

Contingency Planning

Managers must formulate a plan of action to avoid crisis management and significantly reduce the time taken to employ some form of corrective action

- Equipment down time
- Labour problems
- Significant changes in demand
- Supply problems
- Information Technology down time
- Other emergencies

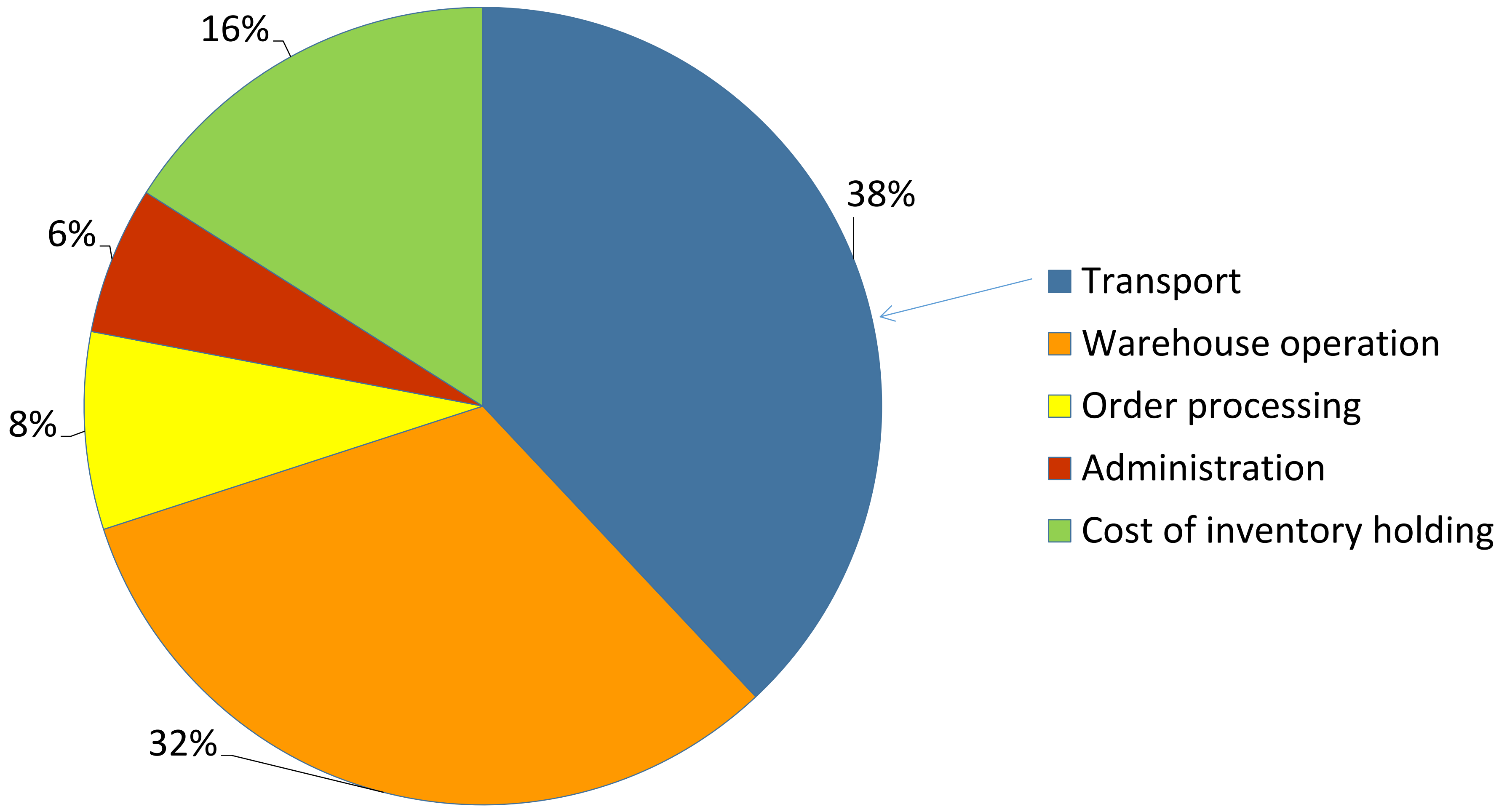
Exercise

- Produce a contingency plan for a breakdown in a warehouse automation system.
  - What are the key things to be included?
  - What do you need to do on a regular basis?

Warehouse Costs

Section 9

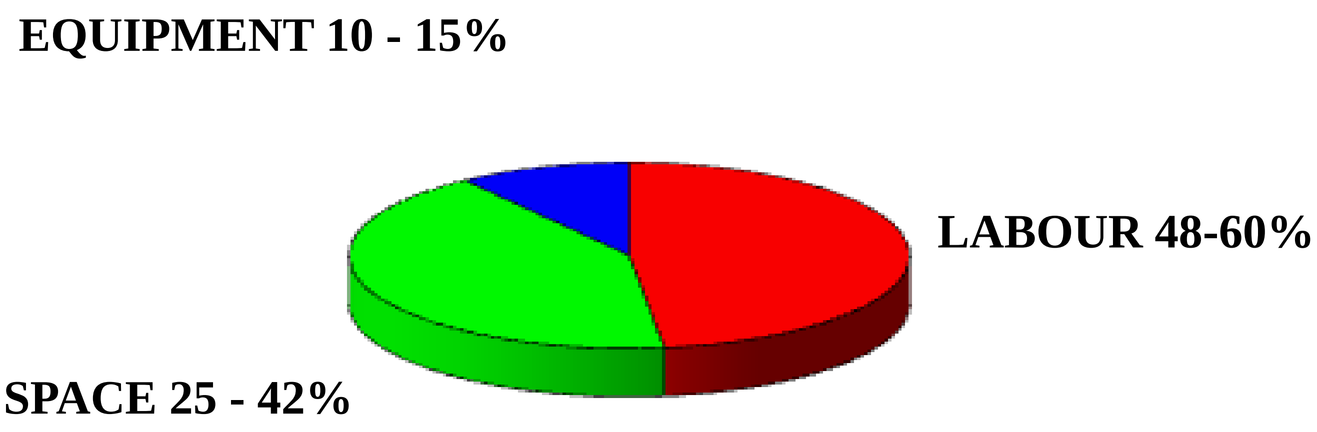
Logistics – Cost factors



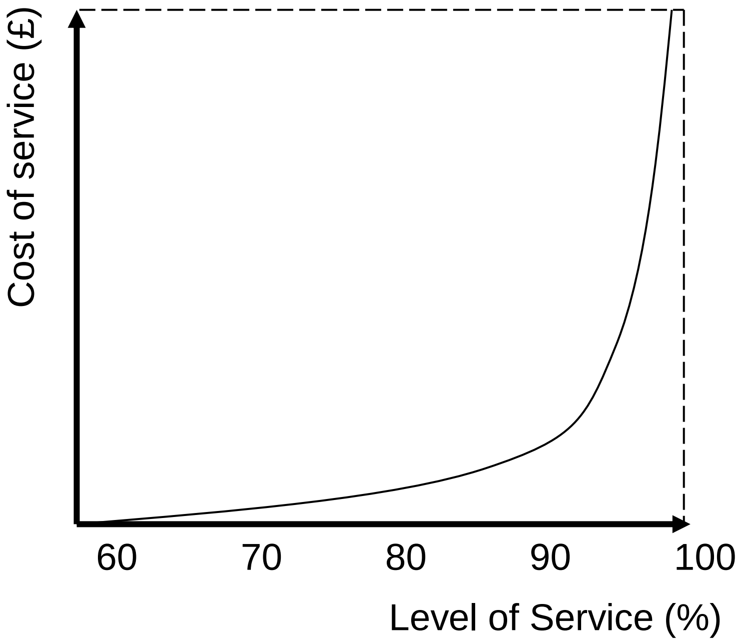
Holding cost includes loss, obsolescence, interest, insurance and depreciation

Warehouse costs

UK Chartered Institute of Logistics and Transport Survey stated that between 24% and 35% of Logistics costs relate to warehouse activity and can be between 2% and 5% of the cost of sales.



Cost of Service improvement



The cost of providing a given service is markedly higher the nearer it reaches the ‘perfect service’ (100%).

Rushton, Croucher and Baker (2010)

Warehouse Costs

A Labour

Salary, Overtime, NHI, Pension, insurance, PPE, holiday pay, sick pay, training
Agency labour

B Equipment

Fork lift truck lease or rental, depreciation and interest, maintenance, energy
Automated equipment depreciation and interest
Cleaning equipment, stretch-wrap machines
Scanners, voice units, pick to light systems depreciation and interest
Pallets and packaging material

C Storage

Facility - lease, rent or depreciation and interest, rates, taxation, insurance, maintenance, landscaping, cleaning, security, sprinkler depreciation and maintenance, alarms, pest control, waste disposal
Equipment – Rack and shelving depreciation, maintenance, inspection

D Utilities

Heat, air conditioning, lighting, water

E Overheads

Management, supervision, administration, office equipment depreciation and interest, IT hardware and software rental or depreciation and interest, maintenance, training, communication costs, legal and professional, taxation and licences, travel expenses, insurance and claims, claim losses due to damages, shortages, errors

Variable costs

Health and Safety

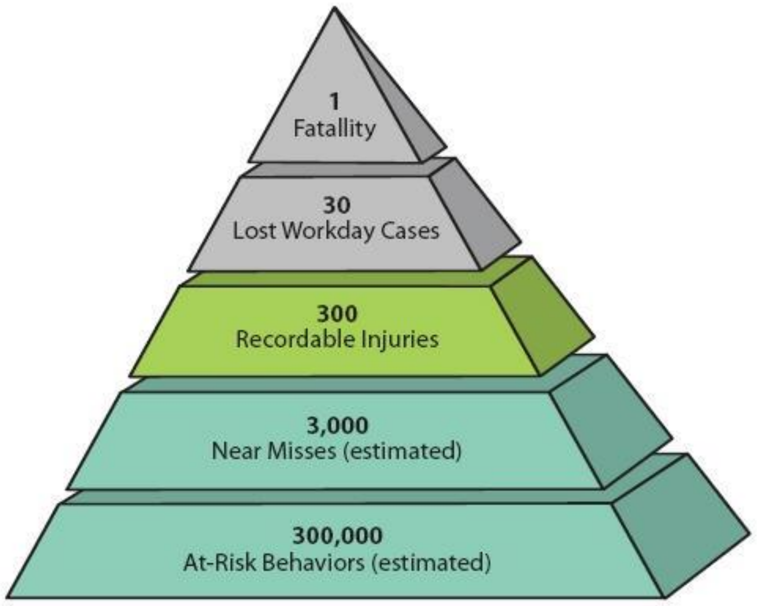
Section 10

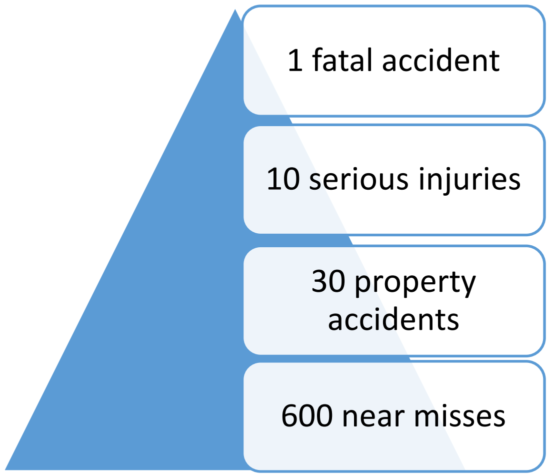
Racking disasters

Nene

Safety Surveys

The Accident Pyramid



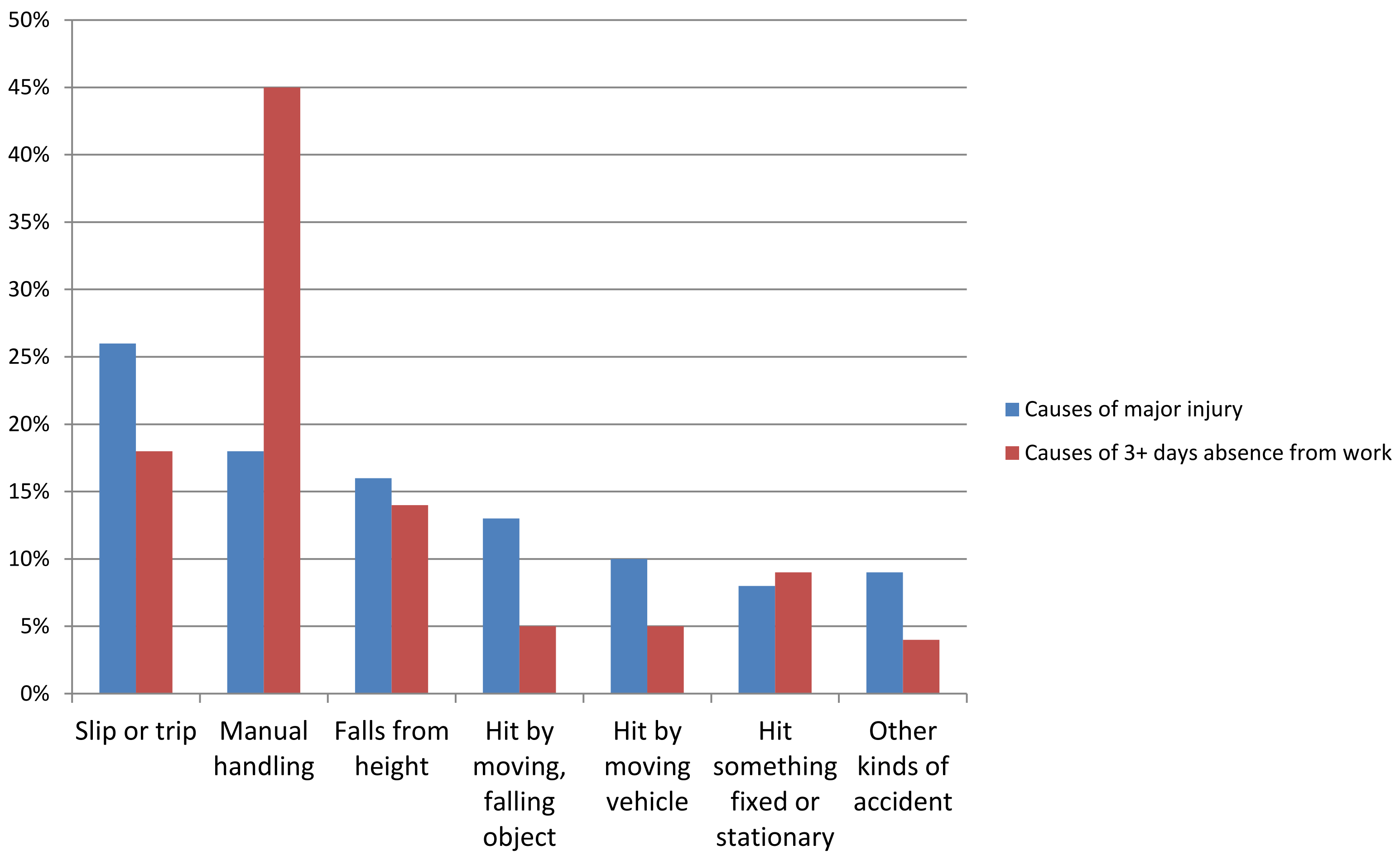


Record, Investigate, Action, Train, Review

www.hse.gov.uk

Continually undertake Risk Assessments!!!

Risk assessment and duty of care



N.B. More litigation than ever before

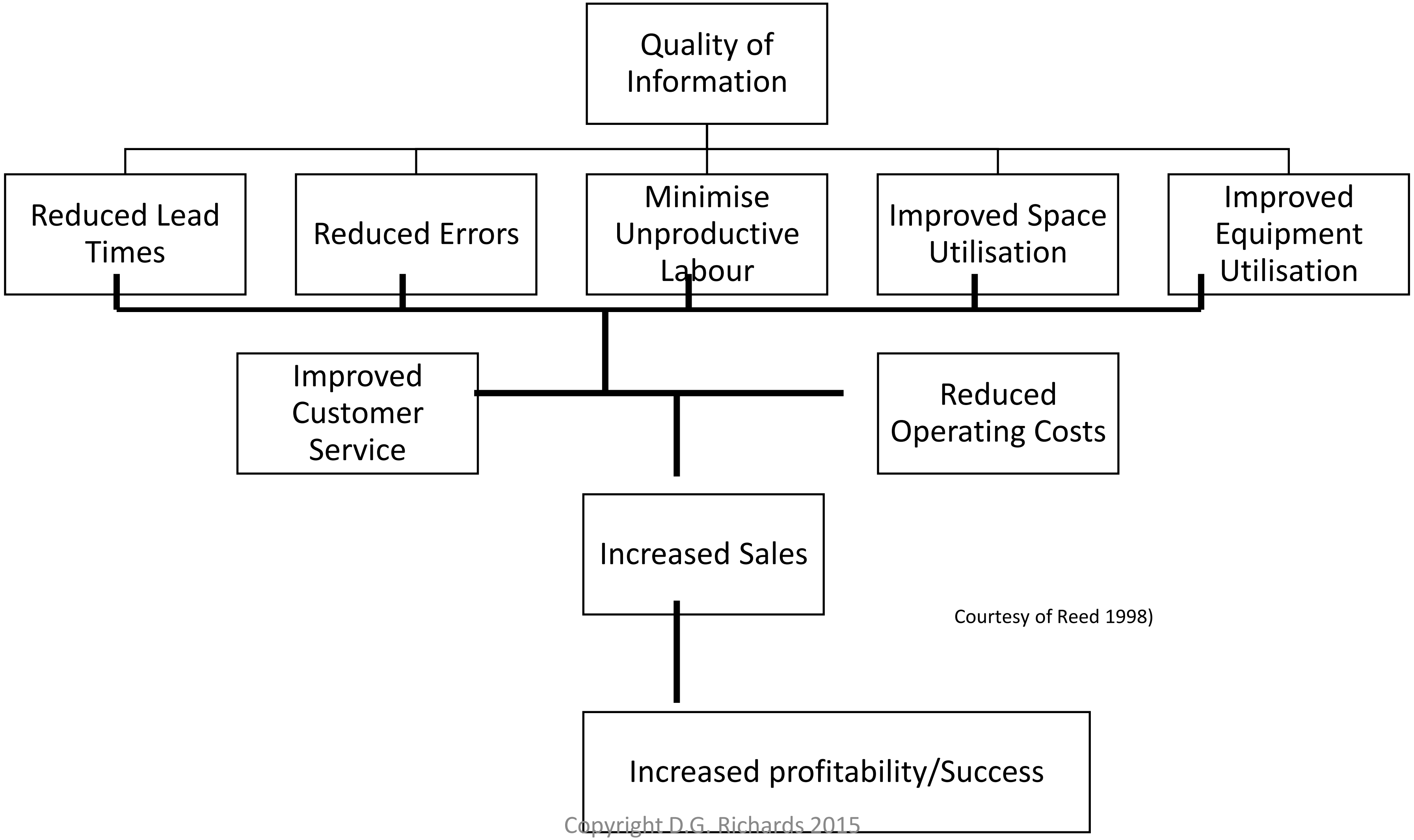
Warehouse Technology

Section 11

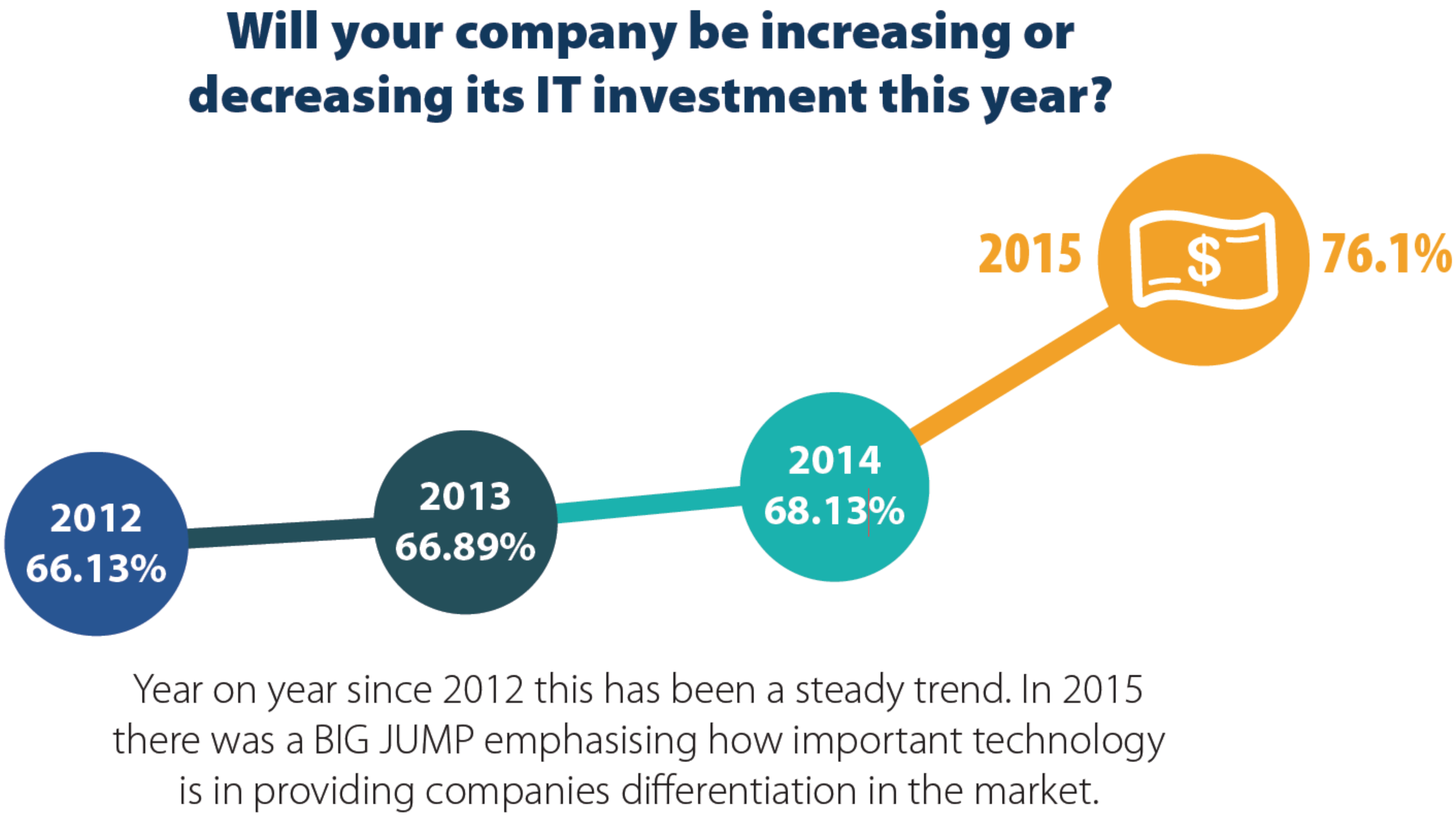
Warehouse Technology

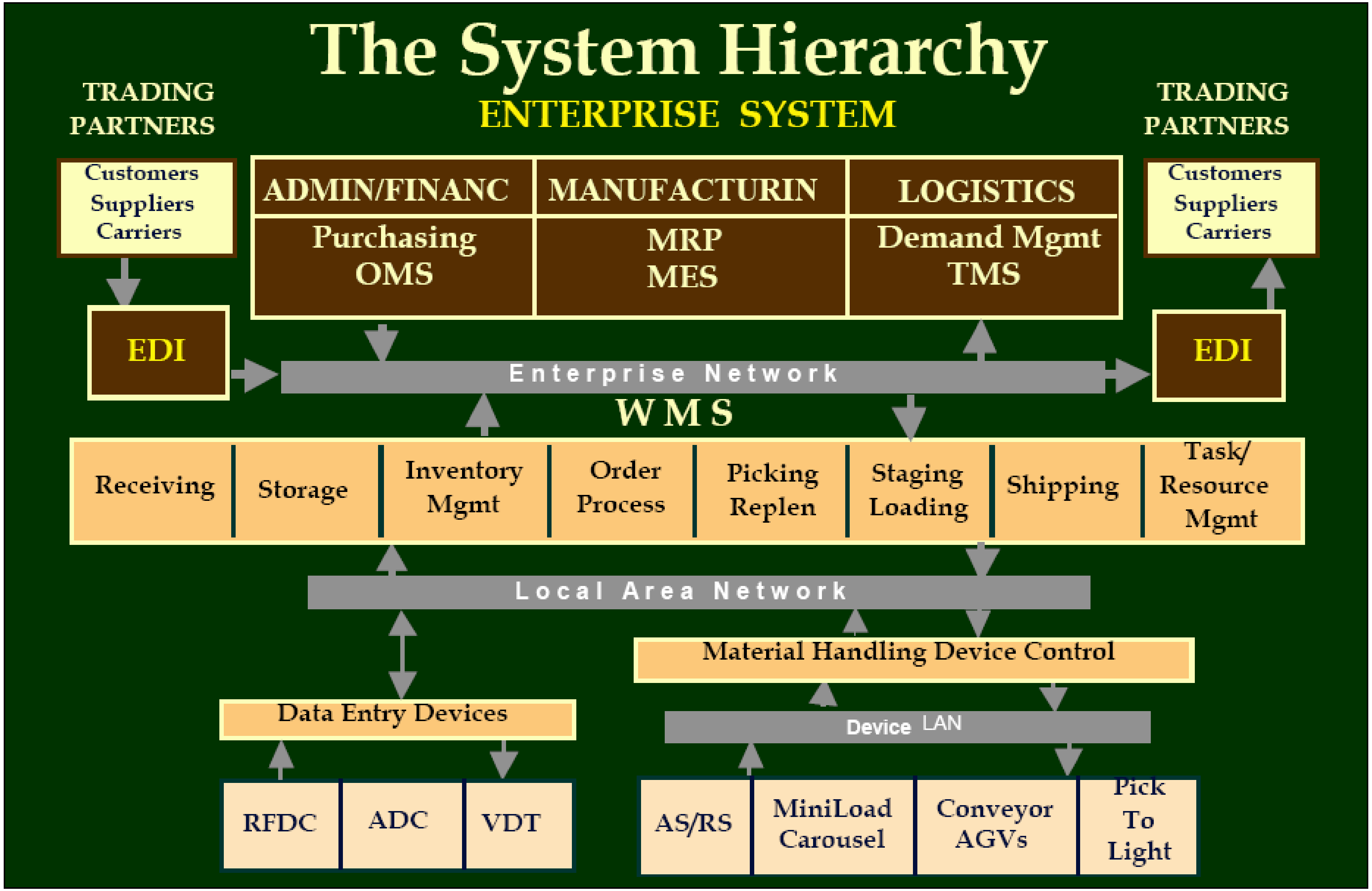
- Warehouse Management System (WMS)
- Automatic Identification and Data Capture (AIDC)
- Radio Frequency Identification (RFID)
- Warehouse Activity Methodologies
  - RF / Barcode Scanning
  - Voice technology
  - Pick to/by light technology

Results / Benefits of effective I.T. systems



Eye For Transport Logistics IT report





Schematic courtesy of the WMS Product Section of the Material Handling Industry of America, Inc.

Best-of-Breed WMS vs. Integrated Suite software such as ERP or SCM

- Typically, best-of-breed applications have deeper functionality than modules within integrated suites. In this case, that means more picking configurations, labour management features, built-in integrations with other technologies, and other warehouse-specific features within best-of-breed applications than WMS modules within supply chain management or Enterprise Resource Planning (ERP) suites.

- Alternatively, buyers may want to evaluate integrated suites if they want a solution that can manage other aspects of the business (accounting, human resources, manufacturing, customer management, etc.) in addition to the warehouse. These vendors are also typically more stable, meaning buyers won’t have to worry about their provider going out of business or being acquired by another vendor.

ERP and WMS systems

- SAP
- Oracle JD Edwards
- PeopleSoft
- Microsoft Dynamics
- Infor
- Syspro
- Netsuite
- Epicor
- Sage

- JDA/Red Prairie
- Manhattan
- High Jump
- Access Delta
- Chess
- ATMS
- Clydebuilt
- Proteus
- Snapfulfil

Adoption of software as a service. (SaaS)

- The initial investment is lower,
- the implementation can be quicker,
- the user interface is familiar (it runs in a web browser)
- companies don't need full-time IT staff to maintain servers and hardware.

Most ERP and WMS vendors now offer - or have plans to offer - some kind of Web-based option.

Why Implement a WMS ?

- Where does the payback come from ?

- To *Reduce Errors* in all warehouse processes.
  - Improving customer service.
  - Reducing the amount of unproductive / non value adding time in the warehouse.

- To *Improve Productivity.*
  - Reducing downtime in the warehouse.
  - Better matching of labour resource with activity.

Warehouse Management System (WMS)
What should it manage within the warehouse ?

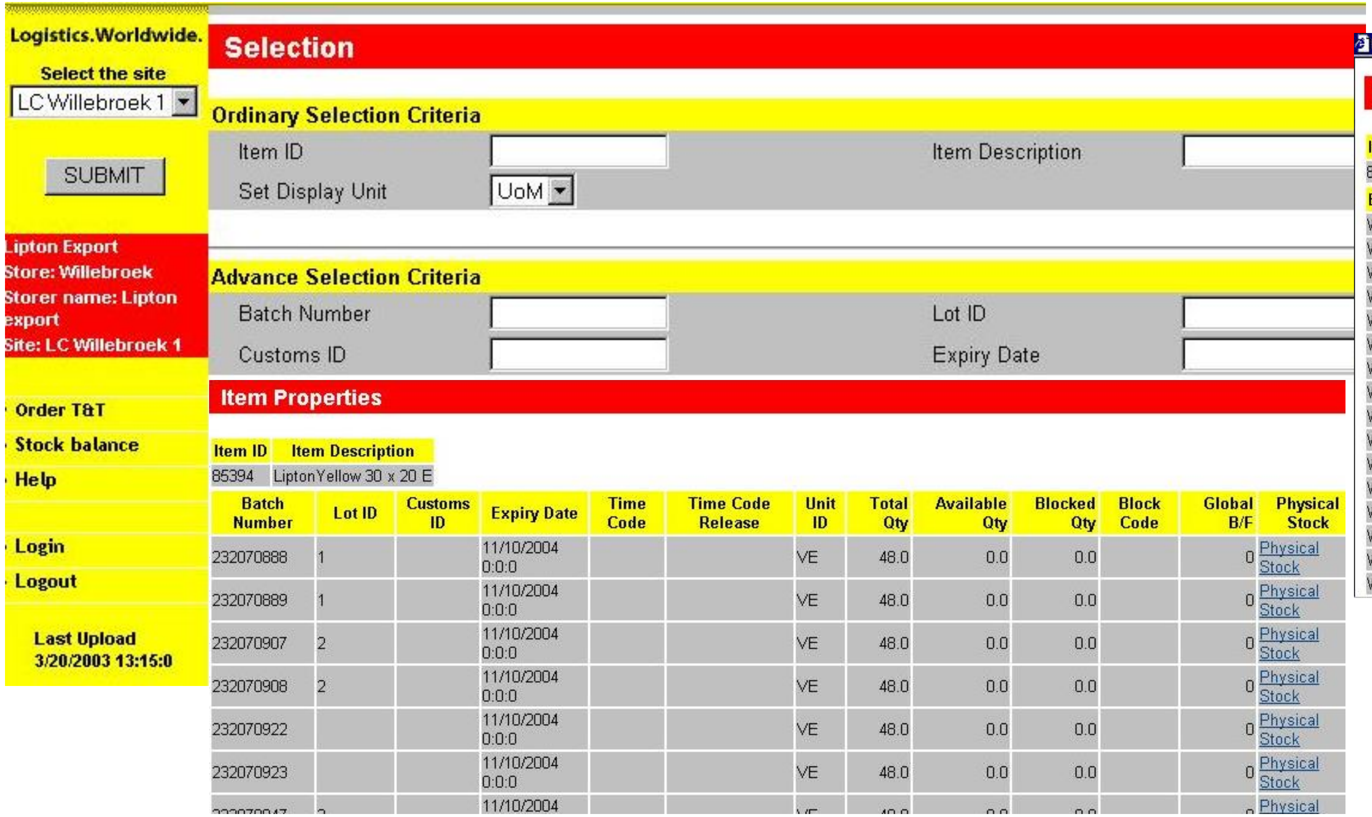
- All processes within the warehouse –
  - Receiving and checking stock
  - Directed put-away
  - Replenishment
  - Task interleaving
  - Processing orders into pick instructions
  - Routing and planning of pick operations
  - Despatch to customer

- Stock location and administration -
  - Optimum stock location and control
  - Slotting
  - Stock Rotation & Traceability
  - Perpetual Inventory and Stock Counts

- Tracking and location of products from source to end user
- Productivity reporting
- Control of multi-site operations

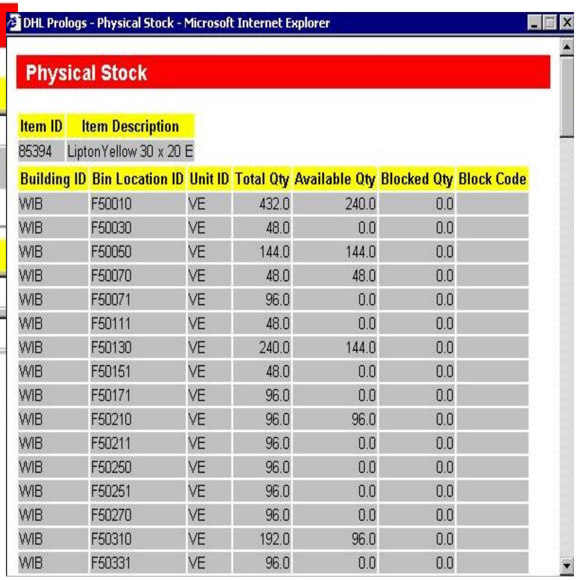
Stock visibility via Internet :

- WMS providing stock visibility and order traceability to customers and vendors



Item ID	Item Description
85394	LiptonYellow 30 x 20 E

Batch Number	Lot ID	Customs ID	Expiry Date	Time Code	Time Code Release	Unit ID	Total Qty	Available Qty	Blocked Qty	Block Code	Global B/F	Physical Stock
232070888	1		11/10/2004 0:0:0			VE	48.0	0.0	0.0		0	Physical Stock
232070889	1		11/10/2004 0:0:0			VE	48.0	0.0	0.0		0	Physical Stock
232070907	2		11/10/2004 0:0:0			VE	48.0	0.0	0.0		0	Physical Stock
232070908	2		11/10/2004 0:0:0			VE	48.0	0.0	0.0		0	Physical Stock
232070922			11/10/2004 0:0:0			VE	48.0	0.0	0.0		0	Physical Stock
232070923			11/10/2004 0:0:0			VE	48.0	0.0	0.0		0	Physical Stock



Item ID	Item Description
85394	LiptonYellow 30 x 20 E

Building ID	Bin Location ID	Unit ID	Total Qty	Available Qty	Blocked Qty	Block Code
WIB	F50010	VE	432.0	240.0	0.0	
WIB	F50030	VE	48.0	0.0	0.0	
WIB	F50050	VE	144.0	144.0	0.0	
WIB	F50070	VE	48.0	48.0	0.0	
WIB	F50071	VE	96.0	0.0	0.0	
WIB	F50111	VE	48.0	0.0	0.0	
WIB	F50130	VE	240.0	144.0	0.0	
WIB	F50151	VE	48.0	0.0	0.0	
WIB	F50171	VE	96.0	0.0	0.0	
WIB	F50210	VE	96.0	96.0	0.0	
WIB	F50211	VE	96.0	0.0	0.0	
WIB	F50250	VE	96.0	0.0	0.0	
WIB	F50251	VE	96.0	0.0	0.0	
WIB	F50270	VE	96.0	0.0	0.0	
WIB	F50310	VE	192.0	96.0	0.0	
WIB	F50331	VE	96.0	0.0	0.0	

Types of WMS – Jacobs (1997) 3 Levels of WMS / History

1980s : WCS – Warehouse Control System	1990s WMS – Warehouse Management System	2000s Integrated System
BASIC	ADVANCED	COMPLEX
▪Stock and location control only	▪Additional facility to plan resources and activity	▪Optimisation of warehouse or group of warehouses
▪Storing and picking instructions	▪Enables synchronisation of activities	▪Full product tracking
▪Simple information focussing on throughput	▪Focus on throughput, stock and capacity analysis	▪Complex storage replenishment, picking and cycle counting strategies
▪Possible links to RF		▪Interfaces with other systems (Route planning, RFID, Freight systems, Customs and Excise
		▪Value added logistics support

Choosing a WMS – What factors to consider

Criteria	Weight	Vendor 1		Vendor 2		Vendor 3		Vendor 4	
		Rate	Score	Rate	Score	Rate	Score	Rate	Score
Software standard function	25	3	75	2	50	5	125	3	75
Software Custom function	20	4	80	3	60	4	80	4	80
Ability to interface with ERP	15	4	60	2	30	4	60	4	60
Hardware supply	15	2	30	3	45	3	45	4	60
RF System	10	3	30	2	20	5	50	4	40
Development/ Implementation service	5	3	15	2	10	4	20	3	15
Annual support/ Maintenance cost	5	3	15	2	10	4	20	3	15
Multi-site cost	5	2	10	2	10	3	15	2	10
Total	100		315		235		415		355

1 = Does not meet minimum requirements; 2 = Does not meet performance requirements by one or more factors

3 = Expected performance; 4 = Exceeds one or more requirements; 5 = Significantly exceeds performance

Tomkins Associates

But a WMS on its own is not enough

- Needs automatic data identification to replace manual data collection.
  - Poor information input = poor information output.
  - Garbage in – Garbage out
- Needs the appropriate technology – RF scanning, voice, pick to light – to compute data and implement control.

Automatic identification (AIDC) methods –

because a WMS is only as good as the information contained within it throughout the warehouse processes.

TECHNOLOGY	DESCRIPTION
Optical Character Recognition (OCR) Readers	Use optics to scan characters that are also readable by an operator
Bar code readers and scanners	Use optical methods to read reflected light from a barcode label
Radio Frequency Identification	Use radio transmission to collect data. The radio waves can travel through most mediums except metal. Doesn’t require line of sight
Voice recognition systems	Instruction relayed direct to operative thus allowing hands free picking
Vision systems	Use camera images to identify characteristics. Able to compare items as well as codes and numbers

Traditional Scanning - Barcodes and barcode readers

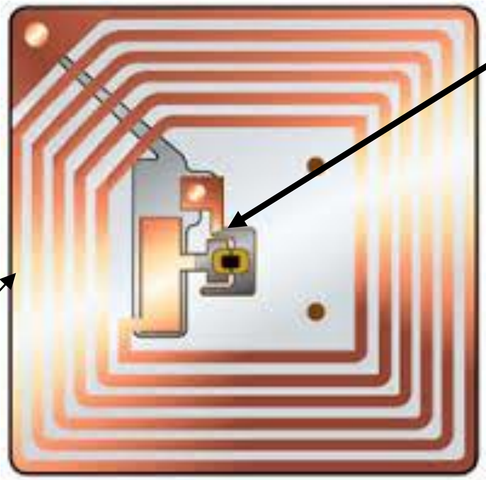
2D image

Advances in scanning

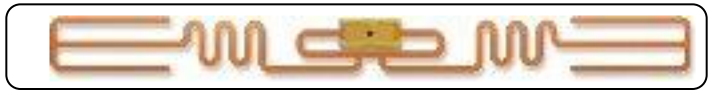
- Finger scanners

Radio Frequency IDentification

Transponder chip holds data

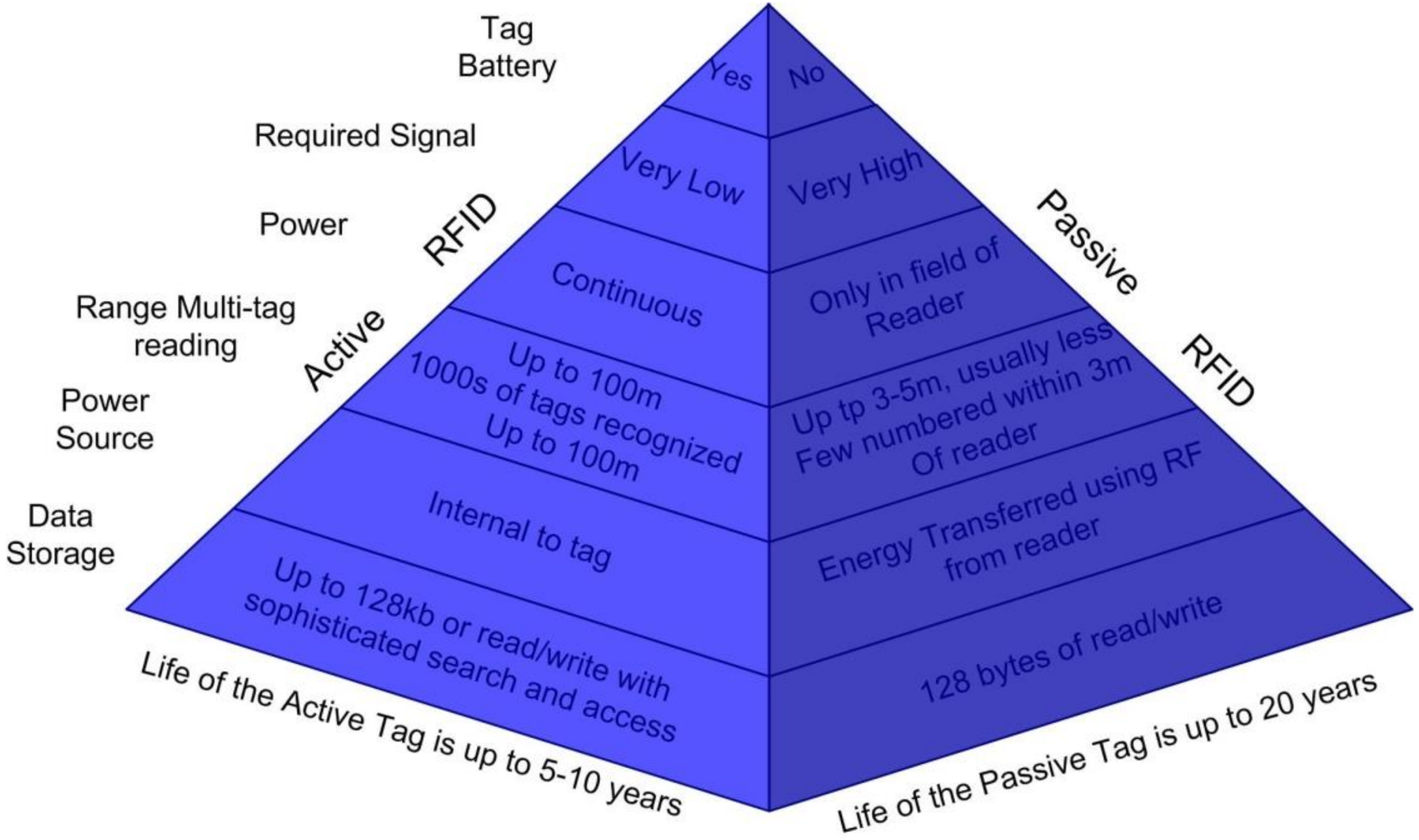


Tag antenna used to power and transmit/receive data



High frequency ID tags

Active v Passive tags



N.B. Some semi-passive tags have a power source

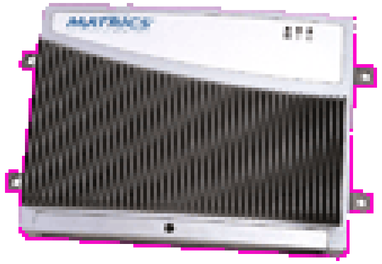
RFID tag readers

Portable
Industrial

Hand Held

Portal

Flatbed



RFID Applications

Closed Loop

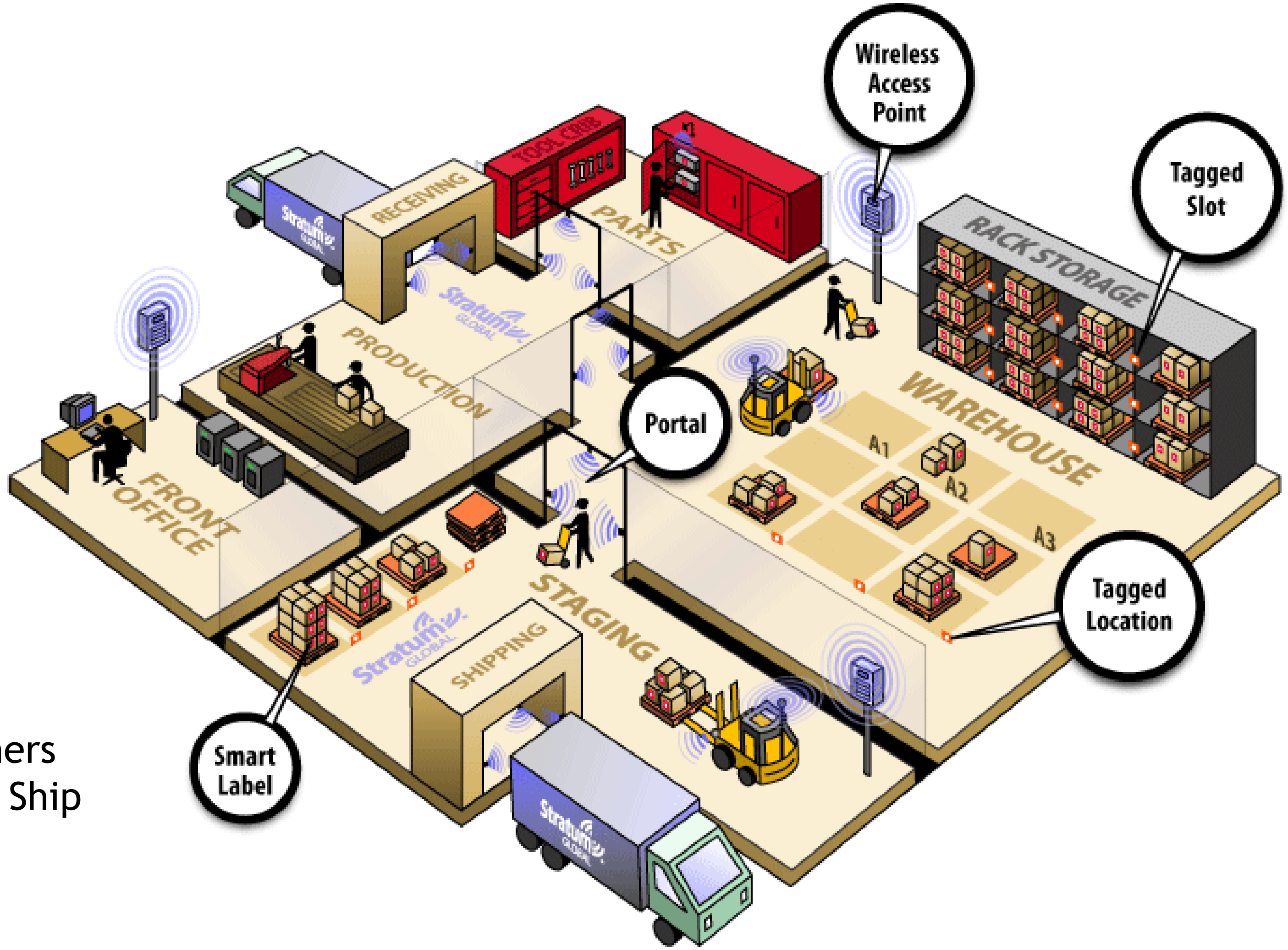
Inventory Management

Asset Management

Any object that has value and needs to be tracked to ensure operational uptime.

EPCglobal Compliance

RFID with Trading partners outside 4 walls. Slap n' Ship for Suppliers.



WMG Innovative Solutions

Use of RFID tags

RFID - Popular beliefs

- *Tags cost pence each*
  - *Tags cost £0.05 minimum (Cheaper tags are in experimental stage but won't be available for an estimated 3 years minimum.)*
- *Multiple tags will read in any orientation*
  - *Tags need to matched to an aerial and generally square to the aerial for best results*
- *RFID will replace barcodes in the next few years*
  - *RFID will only replace 10% barcodes by 2015 (Source AIM Intl. 2003)*
- *All tags can be read from any distance*
  - *Most tags read from 5mm – 2 Metres unless you are paying over £5 per tag.*
- *Tags can be applied to most items*
  - *Most tags have difficulty reading when attached or in the proximity of liquids or metals - A tin of beans is the worst case scenario!*

Comparison – RFID v Barcodes

- 25 trays per dolly
- 36 dollies per vehicle

Portal

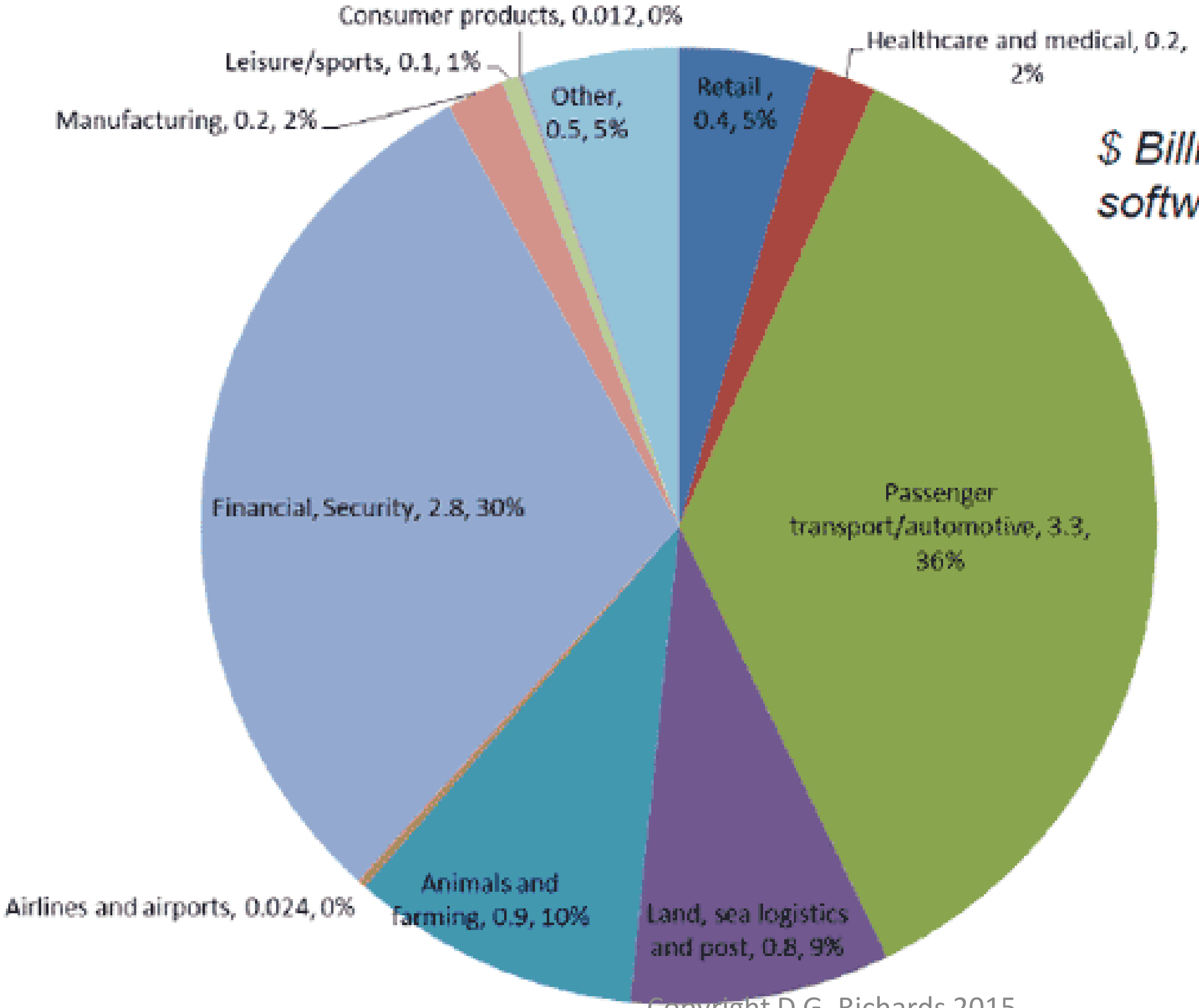
Barcode Scanning = 36 x 29 secs = 1044secs = 17.4 mins

Portal 'Scan' = 36 x 5 secs = 180secs = 3 mins

Reduction in data recording time = 83%

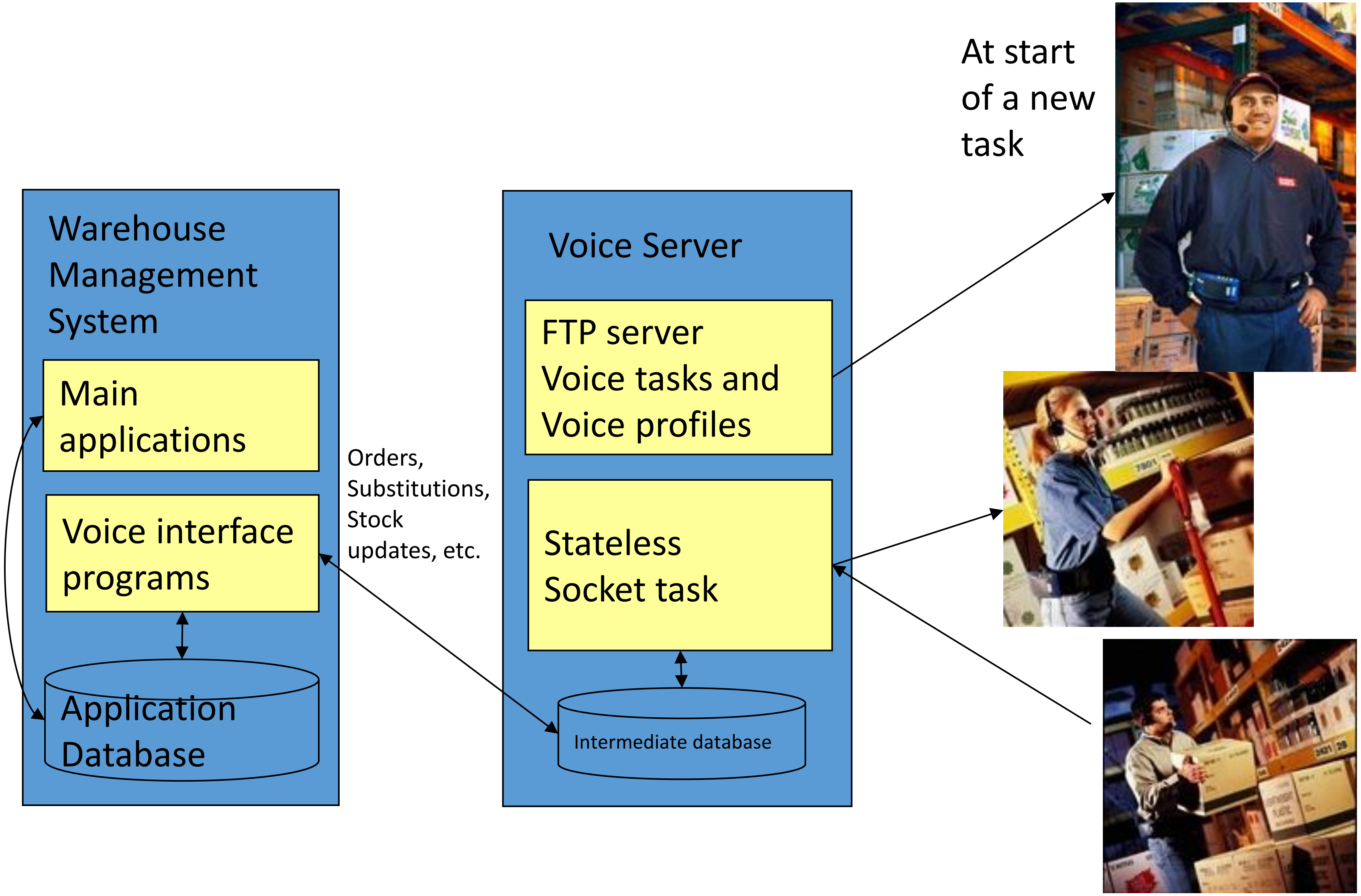
Innovative Solutions

Markets by application 2014



$ Billions, including hardware, software, services

Voice recognition



Why Voice Outperforms Scanning

Elapsed Time

Read Next Location

Travel to Location

Scan Location

Read Qty on Screen

Free Hands Place Device Elsewhere

Perform Task

Locate Device

Press Buttons to Confirm

Hear Next Location; Travel

Speak Check Digits, Hear Instructions, Perform Task

Hear Next Location, Travel

No manual entry, no extra steps,
no wasted time =
better productivity + improved accuracy

Know the Benefits – of Voice

Benefit	Business Impact
Improves Accuracy ☐ Can increase accuracy up to 99.99%	Reduces order fulfillment errors Increases customer satisfaction Reduces cost of resolving issues & processing returns
Improves Productivity ☐ Can increase productivity by 10-25%	Reduces labour required to accomplish new levels of throughput. Helps accommodate seasonal increases without increasing headcount.
Reduces Training Time ☐ Cut Training Time by 50%	Time to full productivity for a new worker for scanning is typically 2-3 weeks; voice is 3-4 days.
Reduce Operating Costs	Reduction in annual cost of scanner equipment, maintenance of systems, (e.g. pick to light), paper/labels/printer costs.
Improves Safety	Eases worker compensation claims leading to reduced insurance costs, etc.
Reduced Administrative Support and Auditing Functions	Need for secondary audits are eliminated

- Somerfield – increase in productivity by 7.9%, accuracy up to 99.97% plus reduction in clerical staff and use of paper
- Waitrose – Productivity increased between 7 and 8%

Disadvantages of voice technology

- Only small amounts of data can be transmitted at one time
- Only sequential picking can take place
- The actual products to be picked are not generally identified
- The possibility of scanning barcodes such as serial numbers doesn’t exist unless additional hardware is provided
- External noise can cause issues
- It can be tiring for the employees after hours of use

Put / Pick to Light

- With Paper picking, RF Scanning and Voice technology, the system moves the person to the product.
- With Put to Light / Pick to Light technology, the person remains within a specific zone or at a work station.

Pick/Put to light - Dematic

Put to light

Cost - €150/location (display) for a smaller installation (e.g. up to 1500 displays), which could descend towards €100/location for a larger installation (e.g. 10,000 displays).

Comparing technologies

Pros and cons

Pick-To-Light

- Cost per Location
- Medium number of Products
- Fast Movers
- 150-350+ picks per hour
- Limited flexibility
- High accuracy
- 2 stage operation if simultaneous pick

Voice Picking

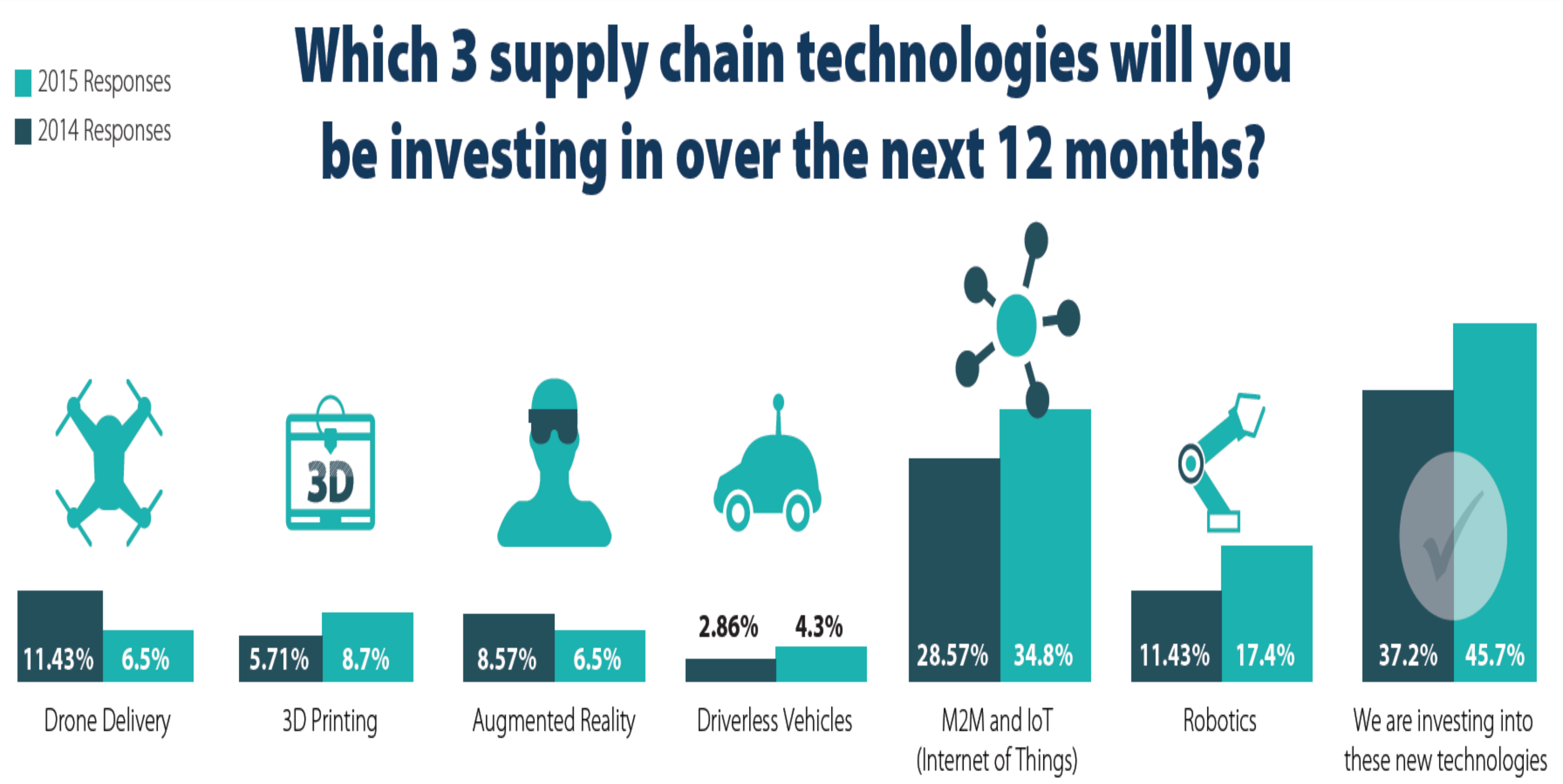
- Cost per Picker
- High Number of Products
- Slow & Medium Movers
- 100 – 200 picks per hour
- Highly Flexible
- High accuracy

Pick rate comparison

Velocity in order lines selected per paid person hour														
Movement category	SKU velocity Category	0	100	200	300	400	500	600	700	800	900	1000	1100	1200
	A							Automated/semi-automated pick technologies						
	A				Horizontal carousels									
	A & B			Pick to light										
	ABC		Voice picking											
	ABC		Visual picking											
	C & D	RF picking												
	C & D	Paper pick												
		0	100	200	300	400	500	600	700	800	900	1000	1100	1200
		Rack and static shelving			Pick to belt carton and pallet flow			Carousels and semi-automated systems						

http://www.mwpvl.com/html/order_pick_technologies.html

IT investment in near future



Summary

- WMS – the essential system that -
  - Controls all the processes in the warehouse.
  - Directs data within the warehouse.
- Accurate data input throughout the warehouse essential – best achieved through automated data capture.
  - Replace manual processes with WMS-controlled automated ones.
- Pick the most appropriate picking / process methodology for -
  - The warehouse.
  - The range and type of products.
- Real time data in most circumstances.
- Improved productivity and reporting.

Warehouse Layout, Planning & Simulation

Section 14

Warehouse layout

Five fundamental process objectives

1. Warehouse designs should be based on throughput not storage
    i. Look at forecasted growth over the next five years
    ii. Evaluate the number type and physical features of the products
    iii. Understand the potential changes in product profiles over the period
    iv. Evaluate type and variability of demand and order profiles
2. Emphasis is placed on eliminating time, space and movement
3. Material and information flow should be properly integrated to avoid delays and uncertainty
4. All issues should be linked to wider business issues
    i. Understand long term market strategy
5. Solutions should be aligned to customer requirements
    i. Potential use of warehouse as postponement centre

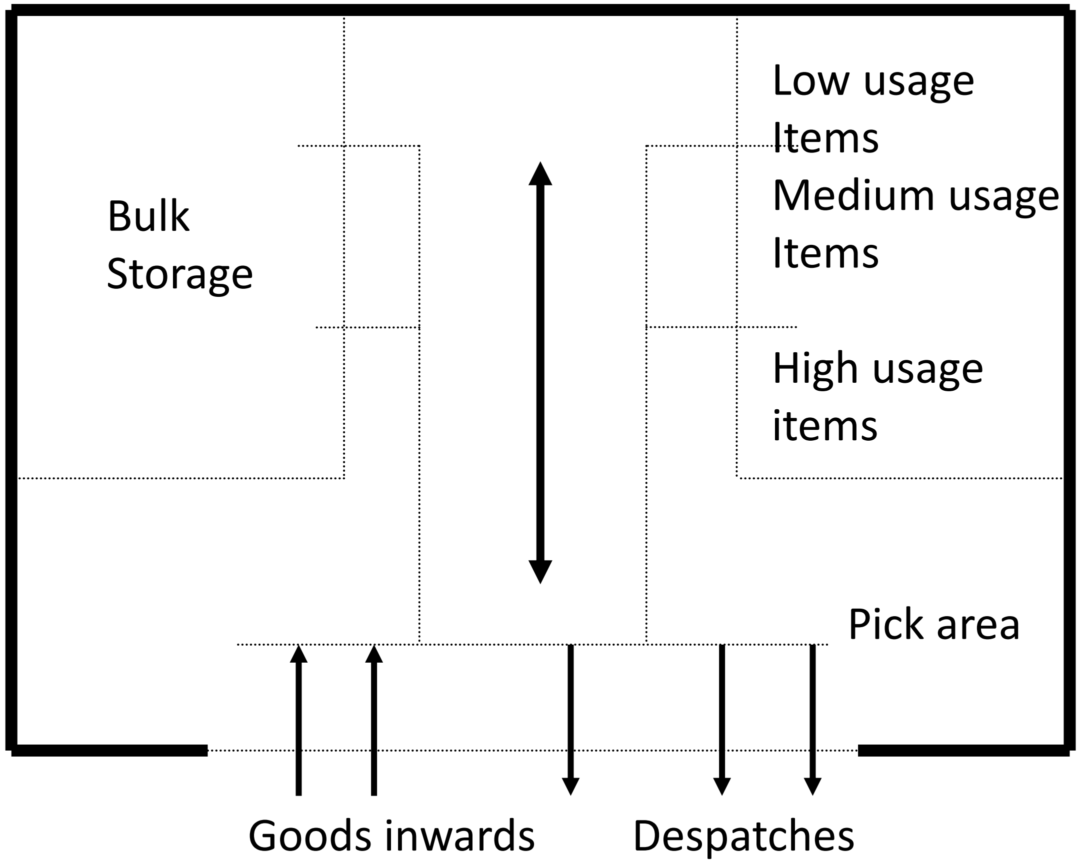
Ballard 1994

Space consumption in the Facility

- Dock Doors
- Storage Mediums
- Personnel Support areas
  - Cafeteria
  - Restrooms
- Shipping and staging areas
- Pre-process and handling areas
- Battery charging, packaging and pallet storage

Warehouse layouts

Inverted 'T' Warehouse Flow

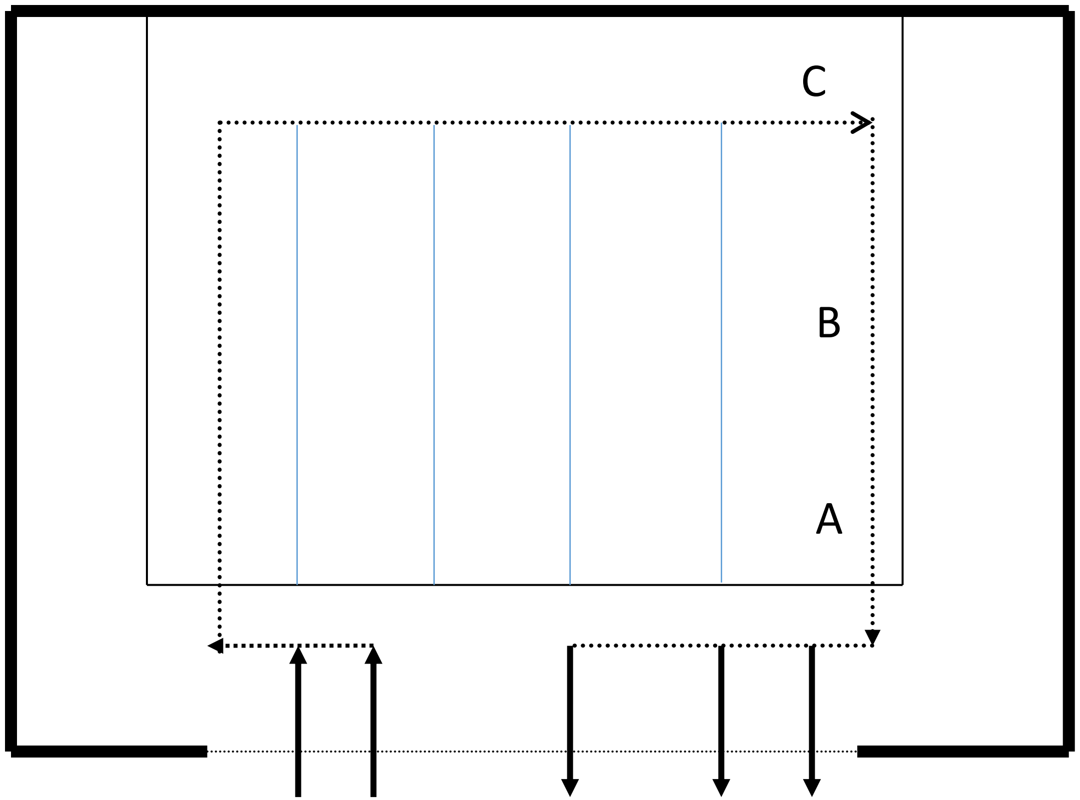


Advantages
- Better utilisation of loading docks
- Reduction in total area required
- Increased flexibility
- Unified management of merchandise flow
- Better security control
- Ability to extend warehouse
- Improve employee comfort and reduce heat loss

Disadvantages
- Congested central area
- Potential friction between inbound and outbound teams

Warehouse layouts

Cross flow or 'U' flow Warehouse



<u>Advantages</u>

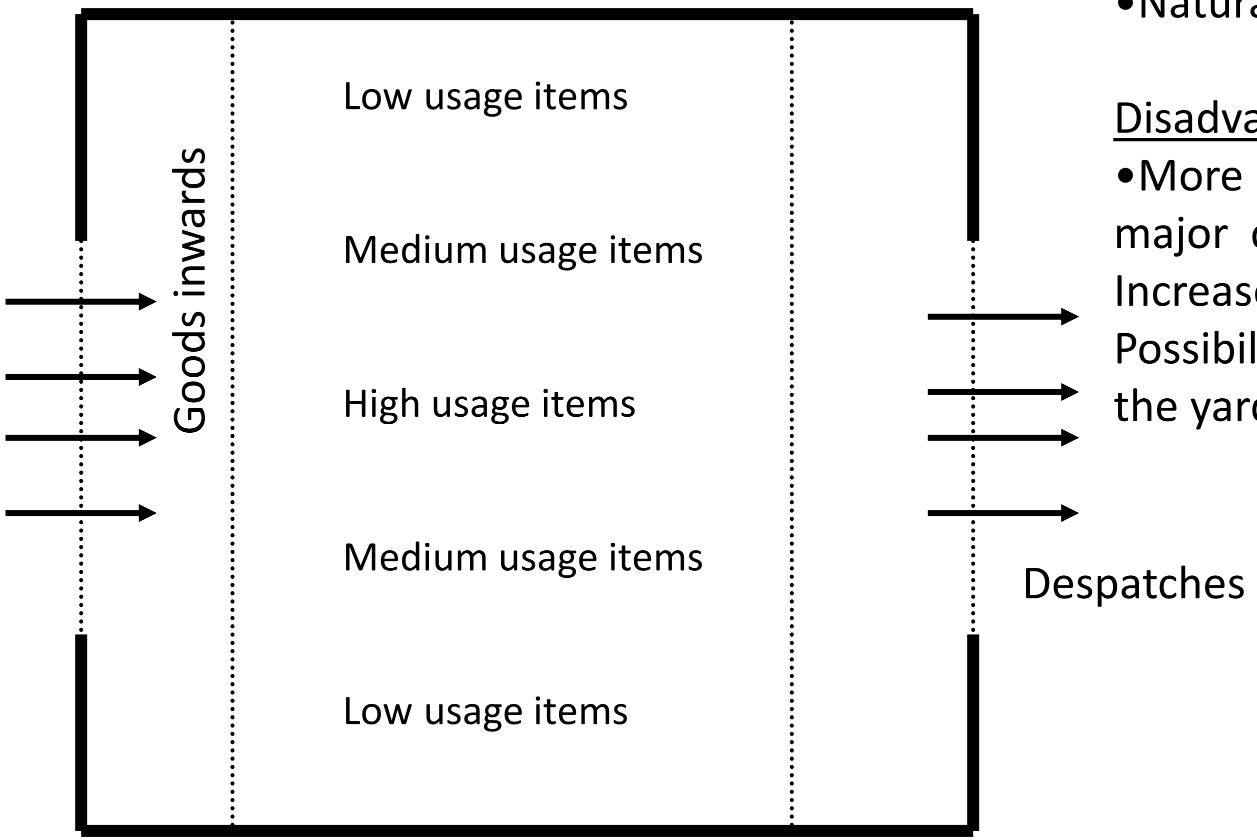
- Better utilisation of loading docks
- Reduction in total area required
- Integration of bulk and picking stocks
- Unified management of merchandise flow
- Better security control

<u>Disadvantages</u>

- Congested aisle areas
- Potential friction between inbound and outbound teams
- Grouped product may not be stored in the same area

Warehouse layouts

Through Flow Warehouse

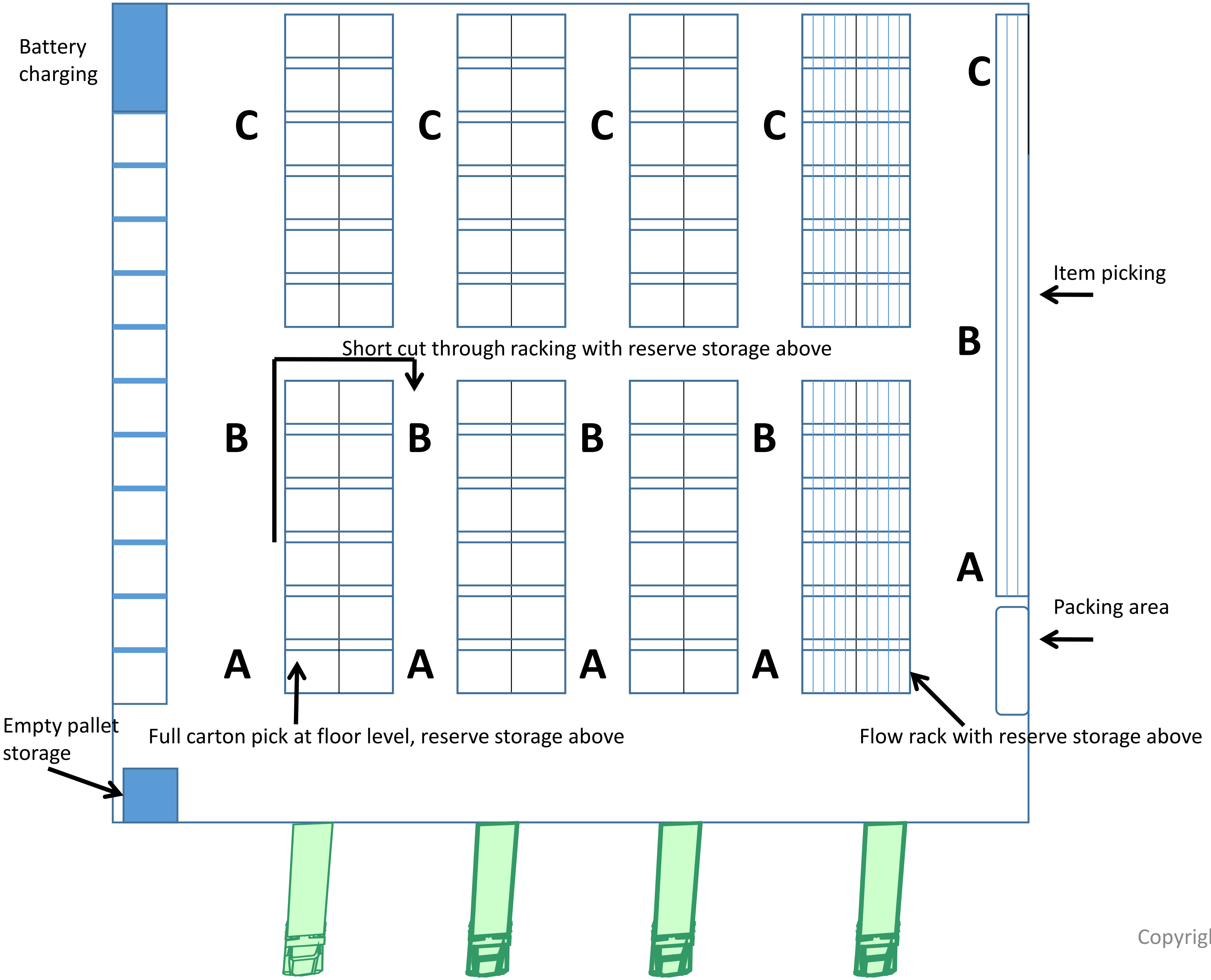


<u>Advantages</u>

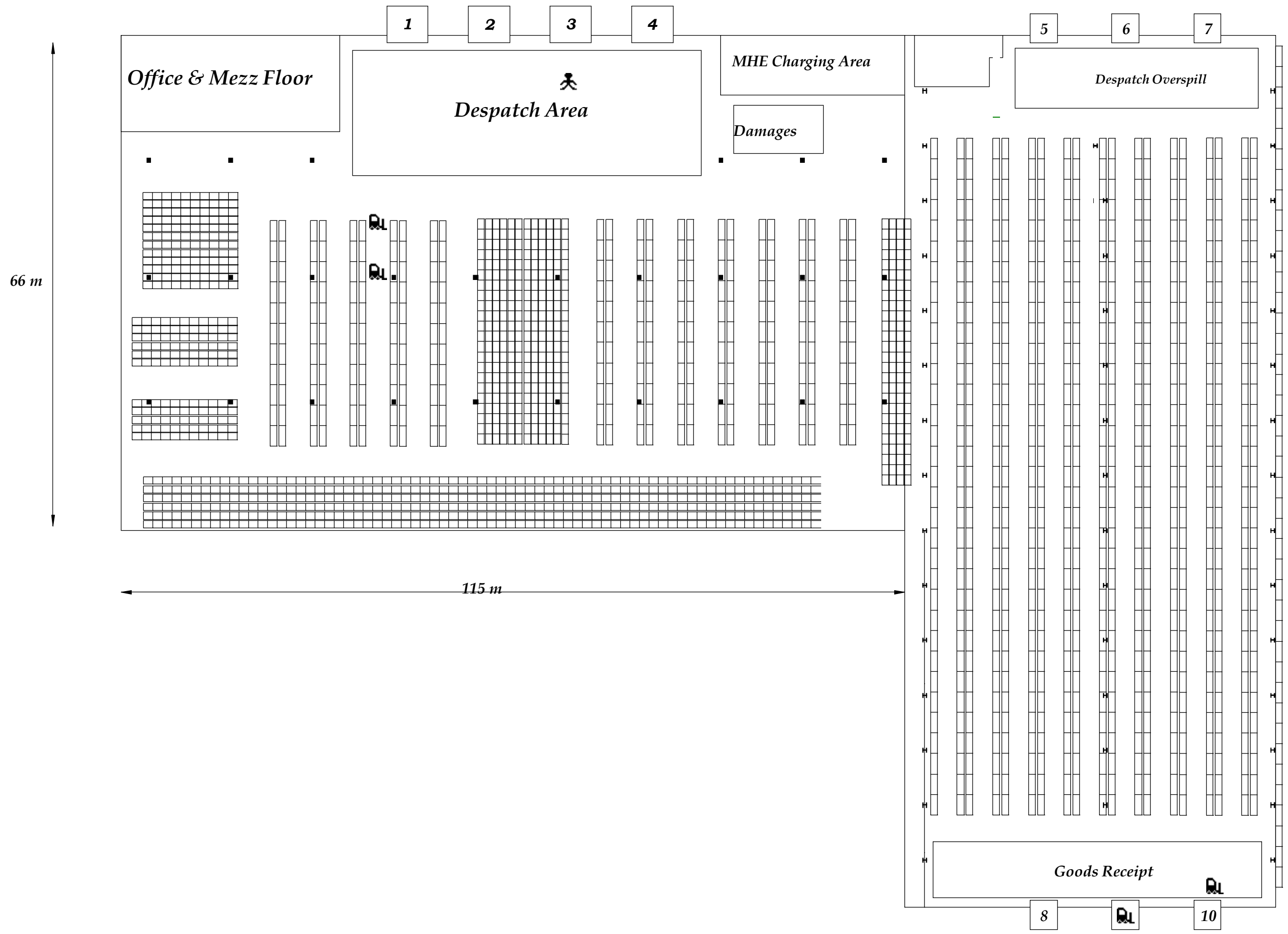
•Less disruption at the loading bays
•Natural flow of goods

<u>Disadvantages</u>

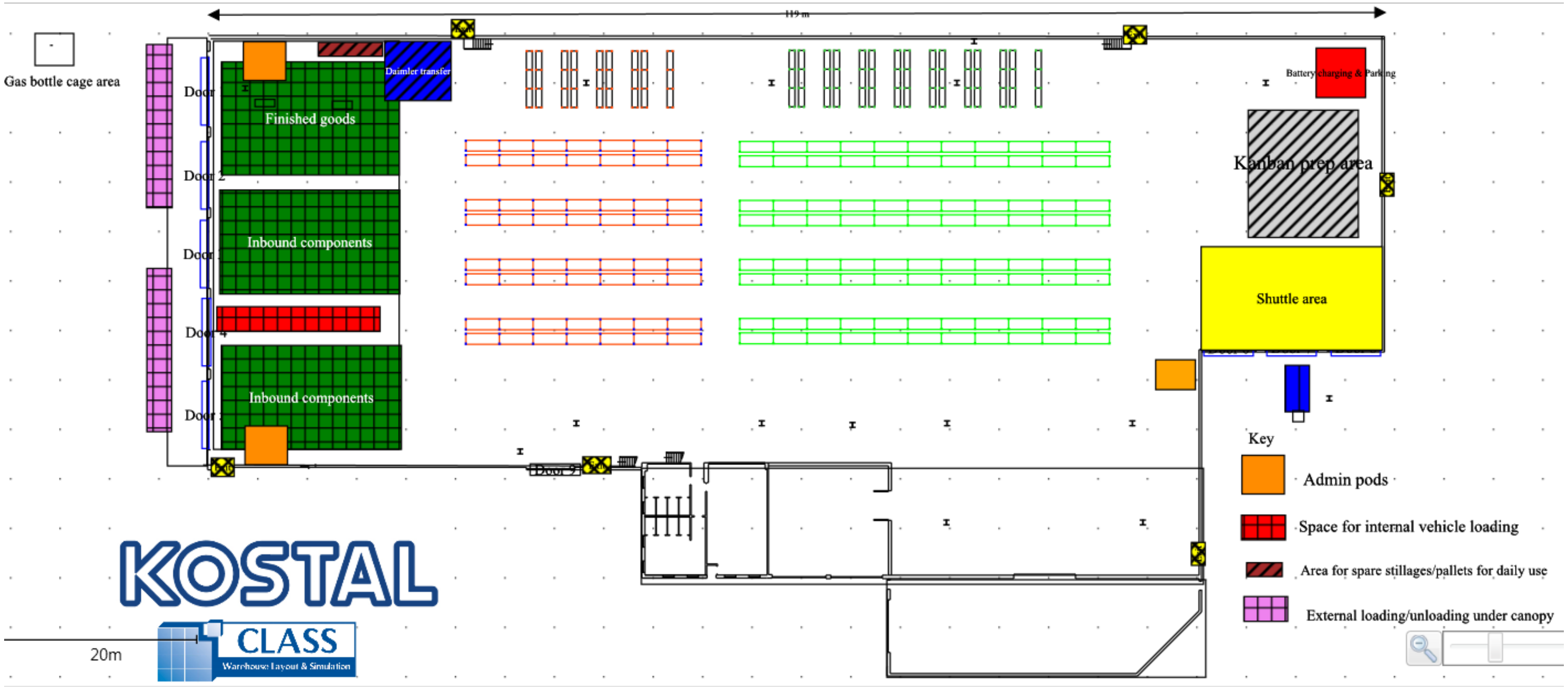
•More difficult to expand without major changes internally
Increase security required
Possibility of requiring 2 exits from the yard


Battery charging
C
C
C
C
C
Item picking
B
Short cut through racking with reserve storage above
B
B
B
B
A
Packing area
A
A
A
A
Empty pallet storage
Full carton pick at floor level, reserve storage above
Flow rack with reserve storage above

Warehouse layout diagrams



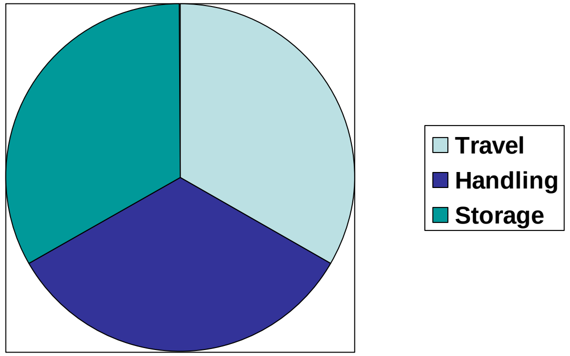
Proposed layout



Not fully to scale.

The Right Answer?

- Typically there is no one definitive answer for your warehouse
- Design is a trade off between travel, handling and Storage



Calculating Dock Requirements

- Using heuristics

- Space =

$$\left\{ \text{Roundup } \frac{(\text{Number of loads x Hours/load})}{\text{time of shift}} \right\} \text{ X } (\text{size of Load x space/pallet})$$

= receiving 20 loads per day

- each load is 26 pallets
- each pallet is 1m x 1.2 m
-45 minutes per load to unload vehicle
- 30 minutes per load to stage prior to put-away
- 8 hours per day work shift

Additionally

- Office space required
- Empty pallet and sundry space requirements

Calculating Dock Space Requirement

- {Roundup (20 x 1.25)/8} x (26 x (1.2 x 1.0))
- = 3.125 (4) x 31.2 = 124.8 square metres

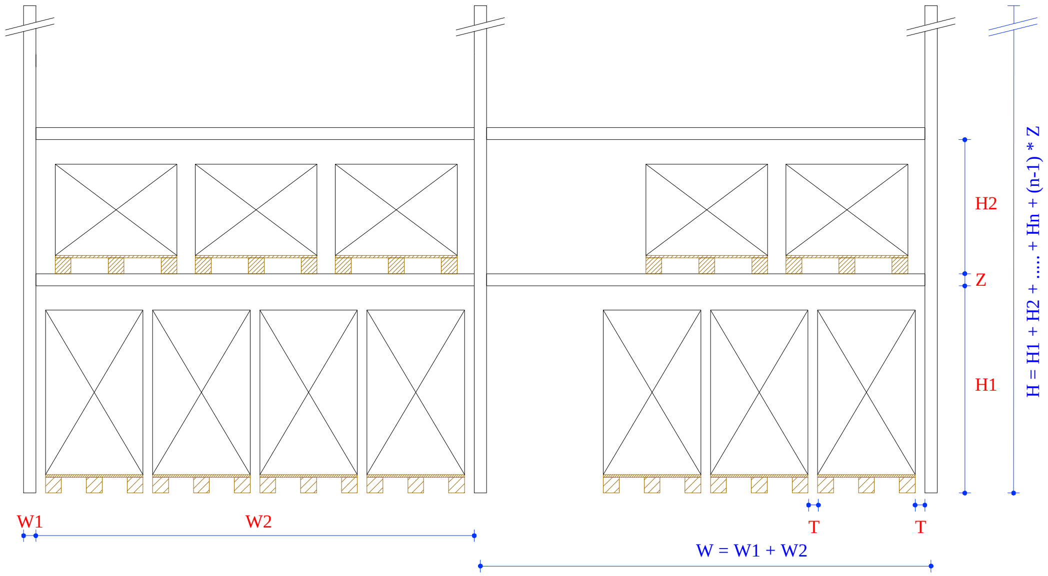
  Dock space = 124.80 sq. metres

  Add double space for working and travel area = 249.60

  Total space = 374.40 square metres

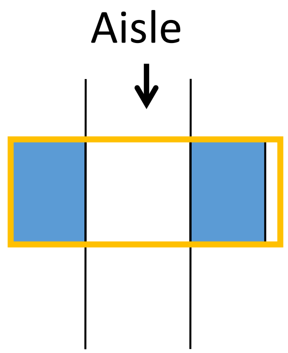
Calculating Storage Space Requirement

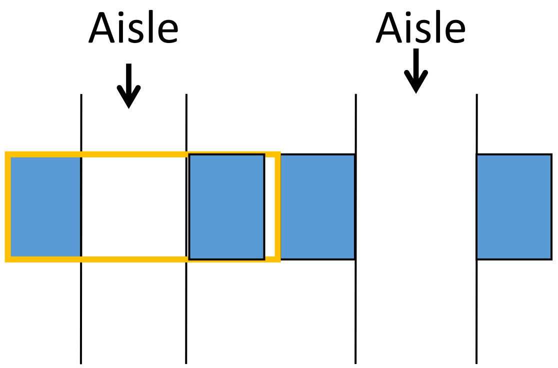
- Determine the type of storage medium and the sq.m./pallet configuration
- Determine the Height of the storage chamber and the max lift height of the MHE
- Include Aisle spacing and work space requirement for the end of the aisle



Pallet quantity calculations - width

Module Width = width of aisle + 2 pallet length (short side) + 100 mm
Aisle = 2,500mm (variable with type of MHE used)
Two pallets = 2,000mm (2 x 1,000mm)
Clearance = 100mm between back to back pallets

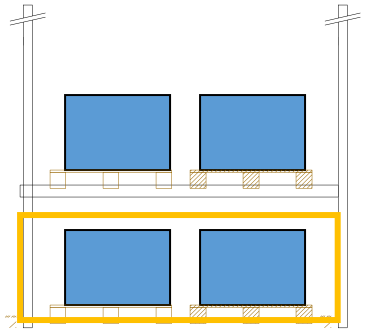




Therefore:
Width of module = 4,600 mm (the sequence is pallet – aisle – pallet - clearance)

Pallet quantity calculations - length

Module Length = width of upright + clearance +2 pallets (long side)
Rack upright plus clearance = 420 mm (120 mm + 3 x 100 mm)
Two pallets (long side) = 2,400 mm (2 x 1,200mm)



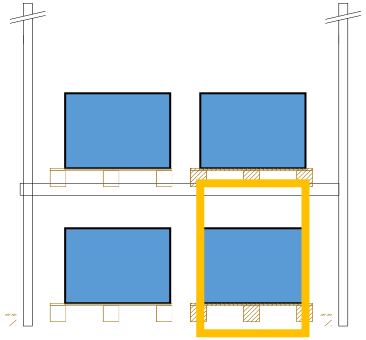
Therefore:
Length of module = 2,820 mm
(the sequence is upright/clearance/pallet/clearance/pallet/clearance)

Pallet quantity calculations - height

Module Height = Height of goods on pallet (e.g. 1.20 metres) + 150 mm (pallet height)
Total Pallet height = 1,350 mm

Clearance above pallet = 150 mm
APR beam width of 140 mm

Therefore:
Height of module = 1,640 mm



Pallet calculation

Total pallets stored within cubic capacity of a warehouse section, excluding receiving and despatch areas, gangways and other areas

(No. of width modules x pallets in module width) x (No. of length modules x pallets in module length) x (No. of height modules) = No. of pallets into cube volume of warehouse.
So for a warehouse section with a width of 48 metres, a length of 120 metres and a height of 10 metres.

Width	= 48/4.6	= 10
Length	= 120/2.82	= 42
Height	= 10/1.64	= 6

Therefore total = (10 x 2) x (42 x 2) x (6) = 10,080 pallet locations in a this warehouse storage space

Plan and Model

Analysis approaches / techniques:

Most common techniques:

- Optimisation

Linear or mathematical programming

- Simulation

Physical scaled down model or computer model

- Analytical

Using numerical tools such as spreadsheets

- Heuristics

Rule of thumb assessment

Bowersox, Closs & Bixby Cooper (2010) &
Rushton, Croucher and Baker (2010)

Plan and Model

Why Model Solutions?

- Discrete event simulation allows the evaluation of operating performance prior to implementation.
- Enables companies to model what-if scenarios leading them to better planning decisions.
- Allows comparison of various operational alternatives without interrupting the real system.
- Allows time compression so that faster decisions can be made.

Why use Simulation?

- Understanding and improving system behaviour
- Tracing bottlenecks
- Testing system performance before commissioning
- Giving customer confidence, satisfy requirements
- Training tool for operators

– *Reduce costs*

– *Save time*

– *Reduce risks*

–*Predictable Productivity*

Sequence of simulation activities

- WHY
- WHAT
- WHEN
- WHO
- HOW

- Collect Data
- Perform flow analysis
- Specify model
- Create (simulation) model
- Verify and validate model

- Define scenarios
- Run scenarios
- Analyse outcomes
- Document results

Yale Warehouse Simulator
Simulation observations

CounterBalanceTruck_ERP20ATF (LWB)-1
Total number of products: 265
Average number of products per hour: 33

31.41%	TravelFull
34.66%	TravelEmpty
0.00%	EnergyFillup
0.62%	Blocked
5.68%	Idle
0.00%	Lifting
18.42%	Positioning
9.20%	DataInput

CounterBalanceTruck_ERP20ATF (LWB)-2
Total number of products: 260
Average number of products per hour: 32

31.28%	TravelFull
35.16%	TravelEmpty
0.00%	EnergyFillup
0.52%	Blocked
6.12%	Idle
0.00%	Lifting
17.93%	Positioning
8.98%	DataInput

CounterBalanceTruck_ERP20ATF (LWB)-3
Total number of products: 255
Average number of products per hour: 32

30.59%	TravelFull
34.51%	TravelEmpty
0.00%	EnergyFillup
0.64%	Blocked
7.74%	Idle
0.00%	Lifting
17.68%	Positioning
8.84%	DataInput

VeryNarrowAisleTruck_MTC15 LWB-1
Total number of products: 252
Average number of products per hour: 32

15.18%	TravelFull
31.07%	TravelEmpty
0.00%	EnergyFillup
0.12%	Blocked
5.80%	Idle
7.00%	Lifting
32.08%	Positioning
8.75%	DataInput

VeryNarrowAisleTruck_MTC15 LWB-2
Total number of products: 248
Average number of products per hour: 31

14.78%	TravelFull
33.44%	TravelEmpty
0.00%	EnergyFillup
0.15%	Blocked
5.08%	Idle
6.34%	Lifting
31.58%	Positioning
8.63%	DataInput

VeryNarrowAisleTruck_MTC15 LWB-3
Total number of products: 248
Average number of products per hour: 31

15.00%	TravelFull
33.85%	TravelEmpty
0.00%	EnergyFillup
0.09%	Blocked
4.21%	Idle
6.81%	Lifting
31.45%	Positioning
8.60%	DataInput

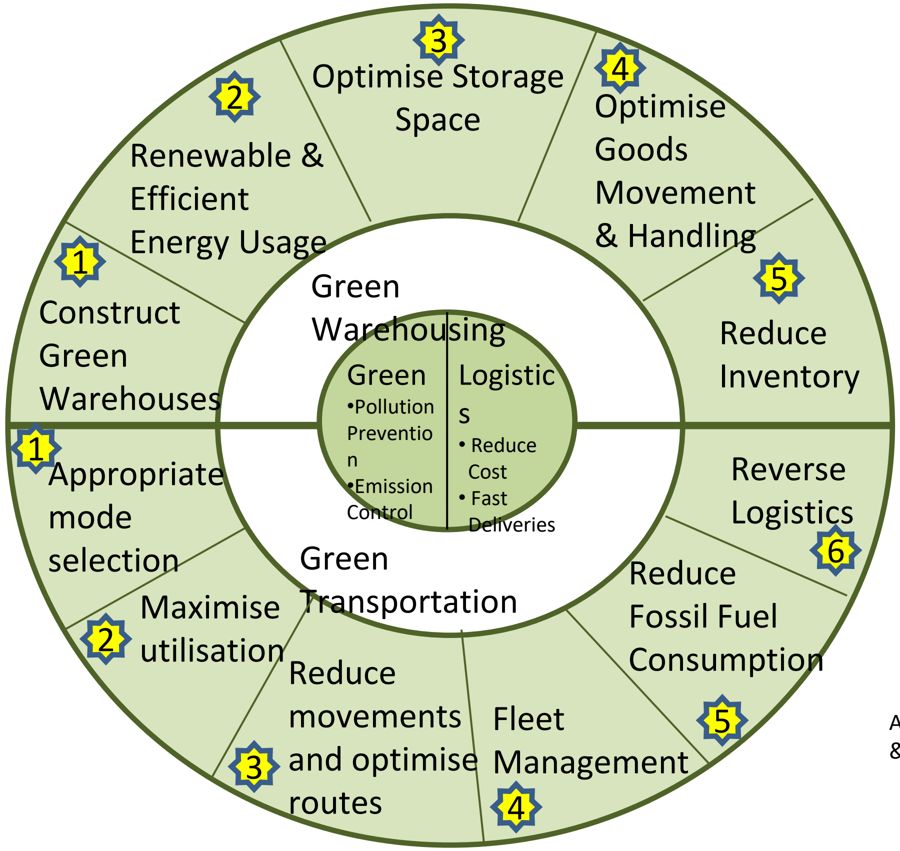
Data requirements

- Product Storage
  - Item length, width, height, weight
  - Pallet Build (TI and HI)
  - Crushability and Toxicity
  - Tote-able
  - Special Pre-Processes
  - Floor Stackable and Height
  - Family Grouping
- Order and Sales
  - Sales over Time (x)
  - Pick Location 'hit' rate
  - Minimum order Quantities
  - Full Pallet or Case/Each Pick
- Business/Rules
  - FIFO
  - Seasonality
- Building/Racking Constraints
  - Flat Floor
  - Ceiling Height
  - Sprinklers, Vents, etc.
  - Pallet Configuration
- Buying/Replenishment
  - Economic Order Quantities
  - Cube fill in Pick Face
  - Min/Max Cartons in Pick face
  - Number of primary pick face slots
  - Buying Multiples – Pallet, TI, Case
  - Number of shifts per day
  - Number of shifts per week
  - Replenishment/Pick Overlap
  - Put-away and replenishment Overlap
  - Replenishment Triggers
  - Minimum Let-Downs
- Productivity & Costs
  - Fixed Costs
  - (Overhead, Racking and MHE, Capital Ex)
  - Variable Costs
  - (Pick rates, receiving, shipping, put-away and replenishment costs)

The Environment and the Future of Warehousing

Section 15

The Wheel of Green Logistics



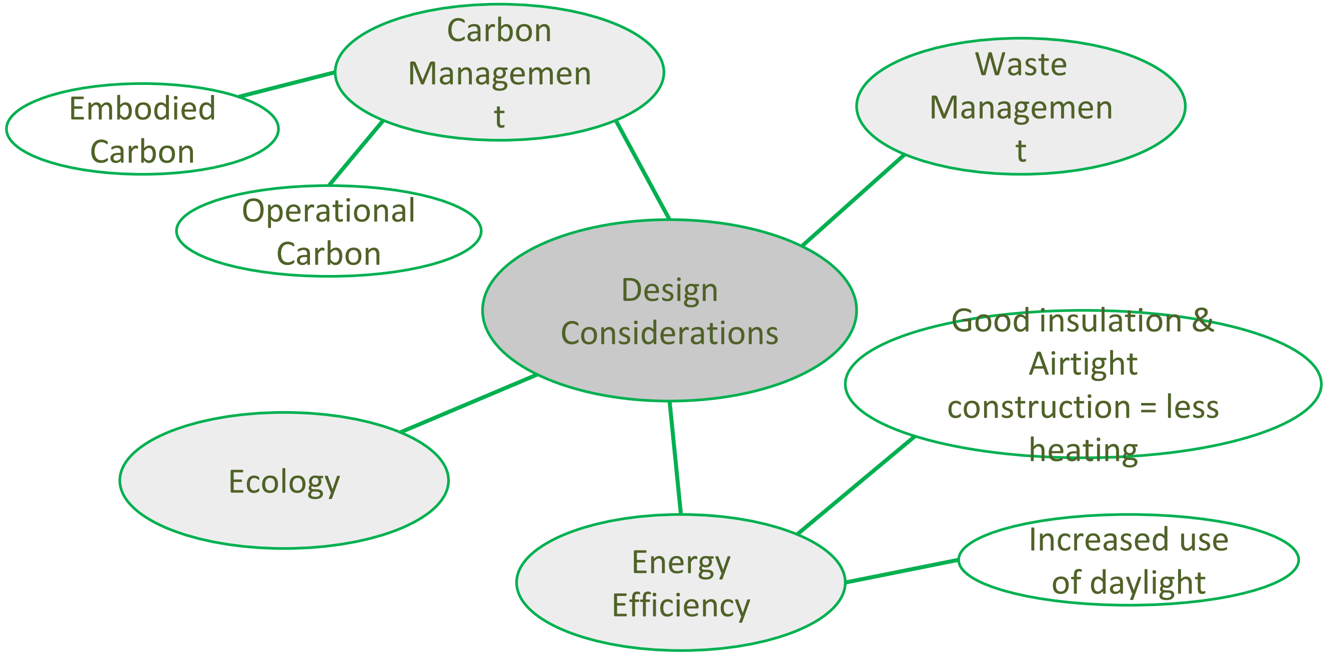
Adapted from Emmett & Sood (2010)

Environmental drivers

- The Environment Act 1995
    - Noise, vibration and visual intrusion
    - Exhaust emission and waste management
- Waste management (WEEE- Waste Electrical & Electronic Equipment)
- ISO 14000- Environmental Management
- Health and Safety
    - Hazardous product handling
    - Ergonomics
        - Absenteeism
        - Fatigue
        - High error rates

Building new warehouses

- Opportunity to 'design in' environmental considerations.



Developed from Dalton, 2009 ProLogis Developments Ltd

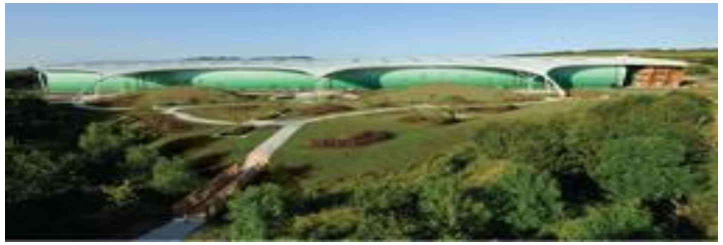
Measurement of Environmental Impact

- Impact measured by Voluntary Sustainable Building Award schemes:
  - BREEAM (Building Research Establishment Environmental Assessment Method) – UK http://www.breeam.org
  - LEED (Leadership in Energy and Environment Design) – USA http://www.usgbc.org/
  - greenstar – Australia http://www.gbca.org.au
  - CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) – Japan http://www.ibec.or.jp/CASBEE/

Has led to developers such as ProLogis delivering warehouses that use 69% less energy and carbon than a typical 15 year old distribution centre.

Example of Eco-warehousing

Gazeley Chatterley Valley Staffordshire UK



http://www.gazeley.com

JCB: Chatterley Valley

M&S NDC, Castle Donington

www.leicestermercury.co.uk

http://www.firstindustrial.co.uk/news/

- 900,000 square feet, 25 metres high.
- Over 140 dock levellers.
- 3 Storey offices.
- Purpose built rail freight terminal.
- Opened in 2013.
- Designed to achieve an ‘Excellent’ BREEAM rating.

M&S Environmental Features

- Carbon neutral.

- Part built using concrete from a former power station.

- UK's largest single roof mounted solar panel array- 24,272 panels. Generates nearly 25% of energy required for the site.

- Rain water harvesting.

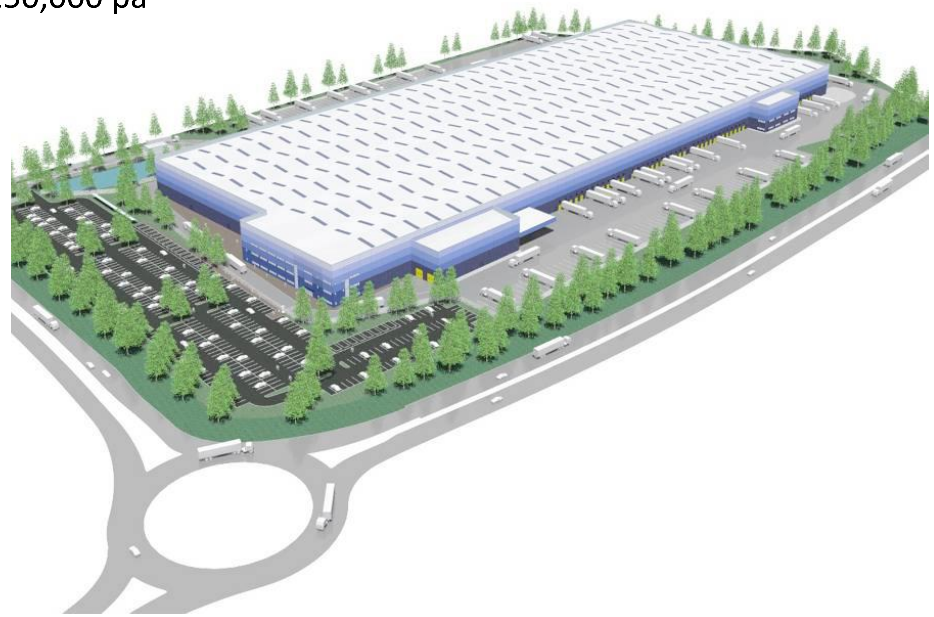
- Airtight building fabric- 4 times as airtight as current building regulations specify.

- Plenty of natural light- roof lights to minimise artificial lighting.

http://www.cagroupltd.co.uk

John Lewis at Magna Park Milton Keynes

- CO_2 Emissions Saving 40% CO_2 pa (1,100,000 kg)
- Energy Usage Saving 18% pa (2,500,000 kwh)
- Water Usage Saving 45% pa (1,500,000 litres)
- Operating Cost Saving € 250,000 pa



The Future

Section 16

The future

- An acknowledgement that reducing warehousing and storage costs is essential
- Introduction of next and same day delivery requirements
- More orders, fewer items
- Automated stores and computerised systems make it possible to better manage these facilities. Greater use of RFID
- Trade-offs between higher customer service levels, low inventory and low operating costs need to be balanced
- Changes in business practices through the implementation of JIT, Lean, Kanban and Kaizen concepts
- Better and easier to use logistics systems, improved supply chain integration, visibility and collaboration
- ‘Time compression’ reducing time consumed in business processes. Elimination of non-value-added time.
- Shortage of good quality staff at all levels
- Ageing population
- Robotics
- Increasing cost of fuel
- The Green agenda

Mega-warehouses?

Quinn Glass Liverpool - 180 x 290 x 35 metres high
250,000 pallet capacity (Courtesy of Stocklin)

Multi-storey warehouses

CWT Commodity Hub
24 Penjuru Road
A multi-storey ramp-up logistics facility comprising a five-storey warehouse with mezzanine office and a separate office block and a container yard

Gross floor area: 2,295,994 sq ft

http://www.colliers.com/

Vision picking

Robotics

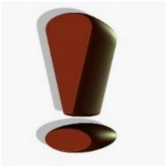
Robotics

Honda's ASIMO

Will we actually need warehouses?

3D printing

Can we 3D print the warehouse?

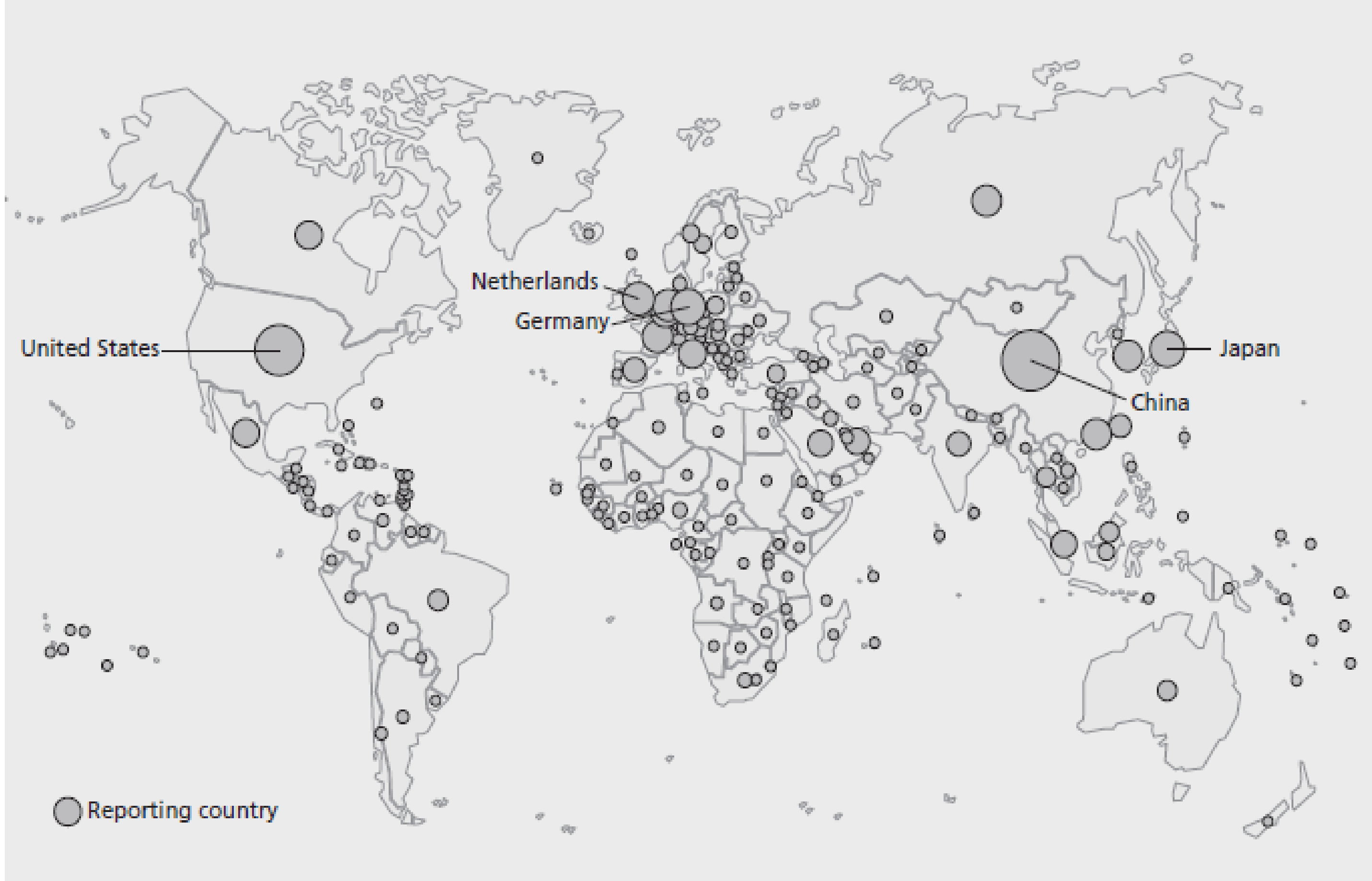


The future – as uncertain as it's always been

GLOBAL SUPPLY CHAINS: THE ROLE AND IMPORTANCE OF TRANSPORTATION

Export-Trade Flows of Merchandise

FIGURE 1-1 Export-Trade Flows of Merchandise



Economy	Million US Dollars
China	2,209,626.00
United States	1,578,971.70
Germany	1,452,795.40
Japan	715,097.20
Netherlands	663,524.30
France	579,646.90
Korea, Republic of	559,632.00
United Kingdom	541,348.00
Hong Kong, China	535,546.00
Russian Federation	523,327.00
Italy	517,673.30
Belgium	468,817.80

Development of Supply Chain Concept

The extended enterprise or boundary spanning perspective, focusing on system of connected networks between the original vendor and the ultimate final consumer

1990s Supply Chain Management

Focus on coordination between the outbound and the inbound sides of logistics, analyzing both trade-offs for total cost and the value of demand aspects of customer service effectiveness

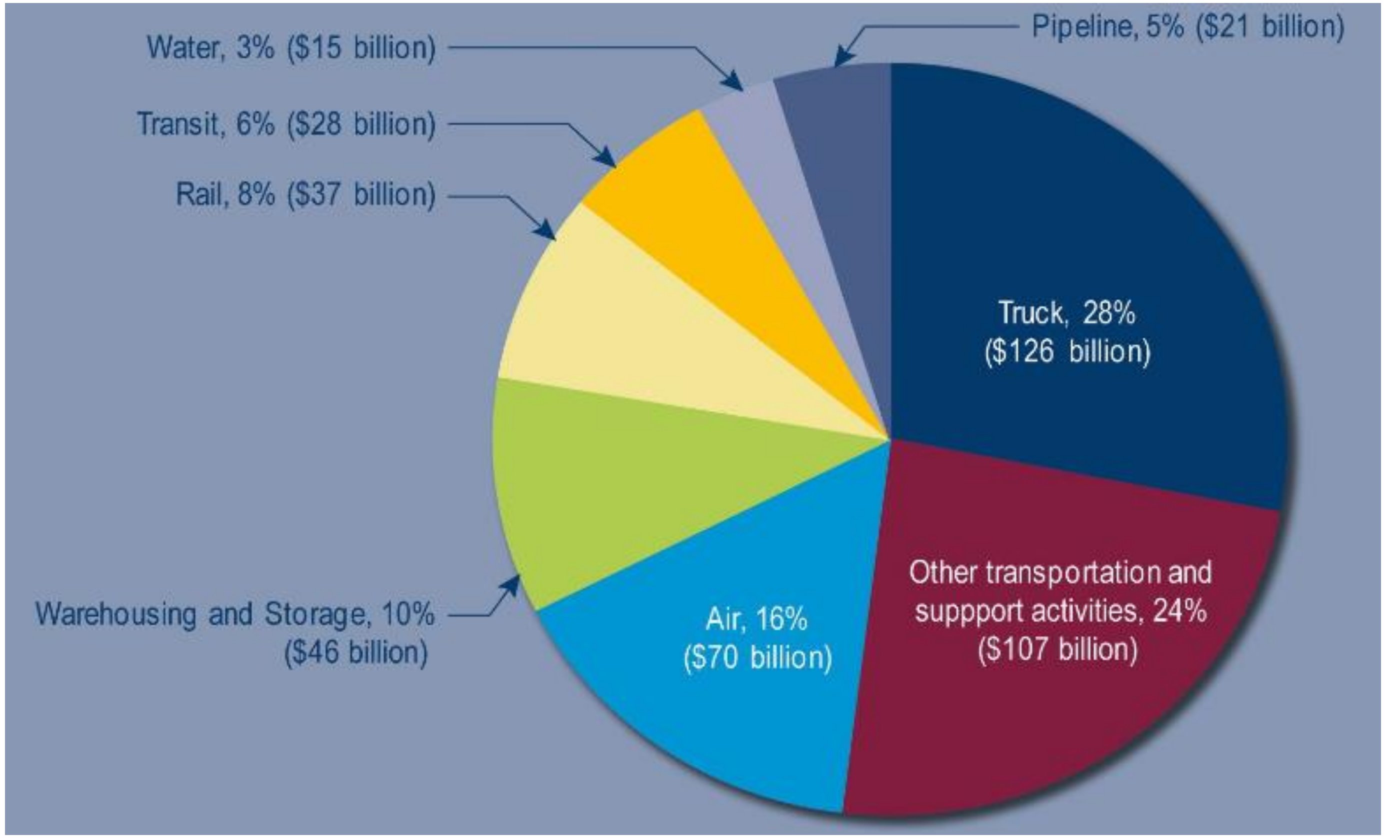
Business Logistics / Integrated logistics **1980s**

Focus on system costs and trade-off among transportation, inventory levels, warehousing, protective packaging, materials handling, and customer service

1960s Physical Distribution

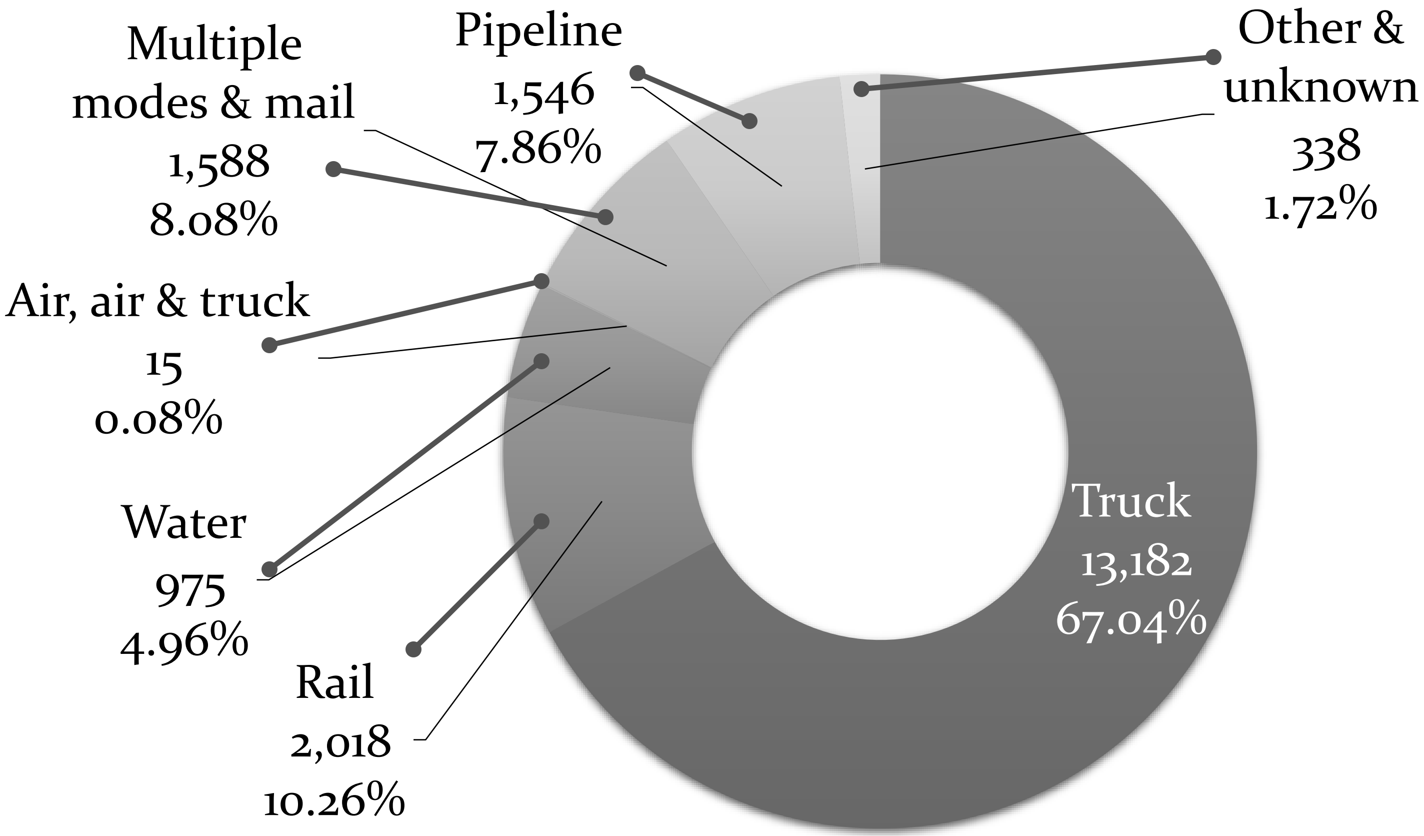
Transportation Importance to GDP

For-Hire Transportation Services Contribution to GDP by Mode: 2011



Source: Freight Facts and Figure 2013, Figure 4-1

Freight Transport Modal Split by Weight
(Millions of Tons, 2012)



Source: Freight Facts and Figure 2013, Table 2-1. Weight of shipments by mode

Value of Transportation Service

The impact of transportation costs and service on the demand for the product

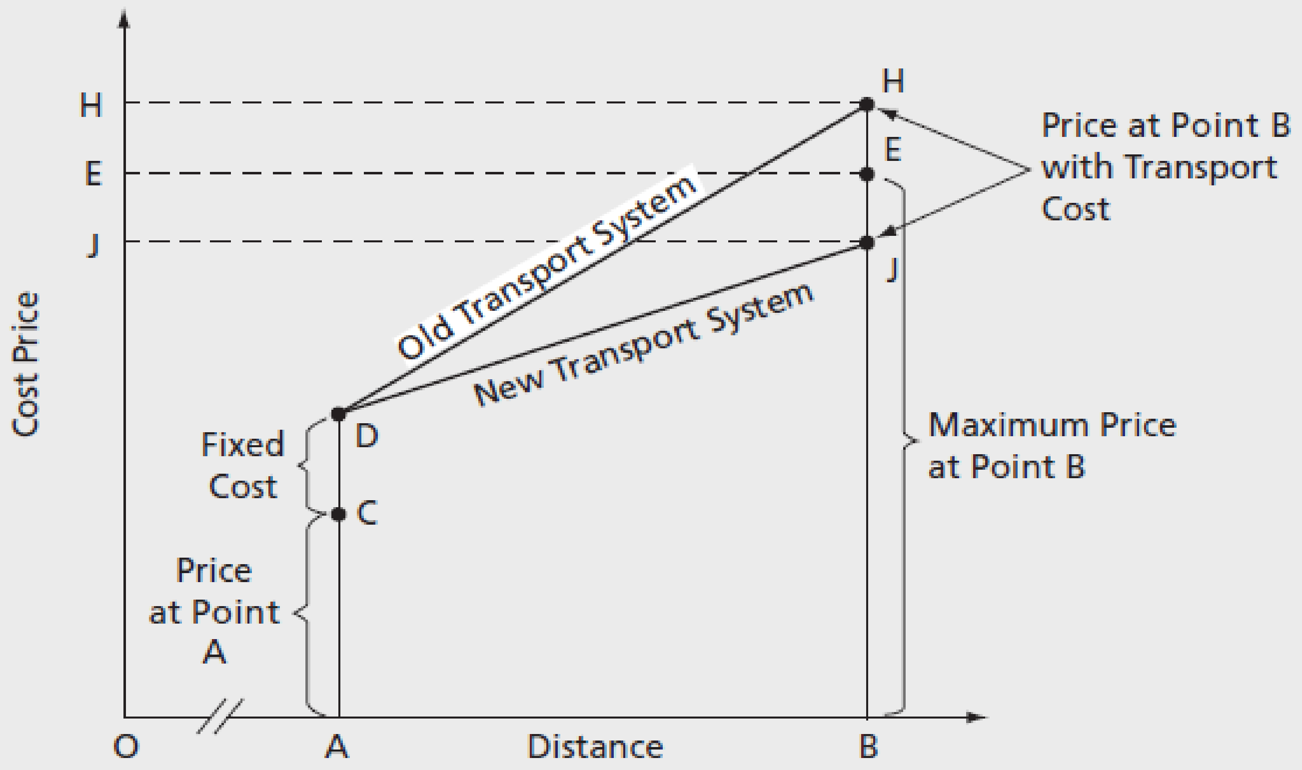
Landed Cost Example

1 Production cost of overseas supplier + 2 Overseas warehouse & transport costs + 3 Export tariffs + 4 International freight transportation costs + 5 Import duties + 6 Buyer warehouse & transport costs = 7 Landed costs at buyer facility

Adapted based on image courtesy of Transways

Landed Cost Impact on Value of Goods

FIGURE 2-4 Landed Cost with Old and New Transport Systems



Utilities of Transportation

Place utility

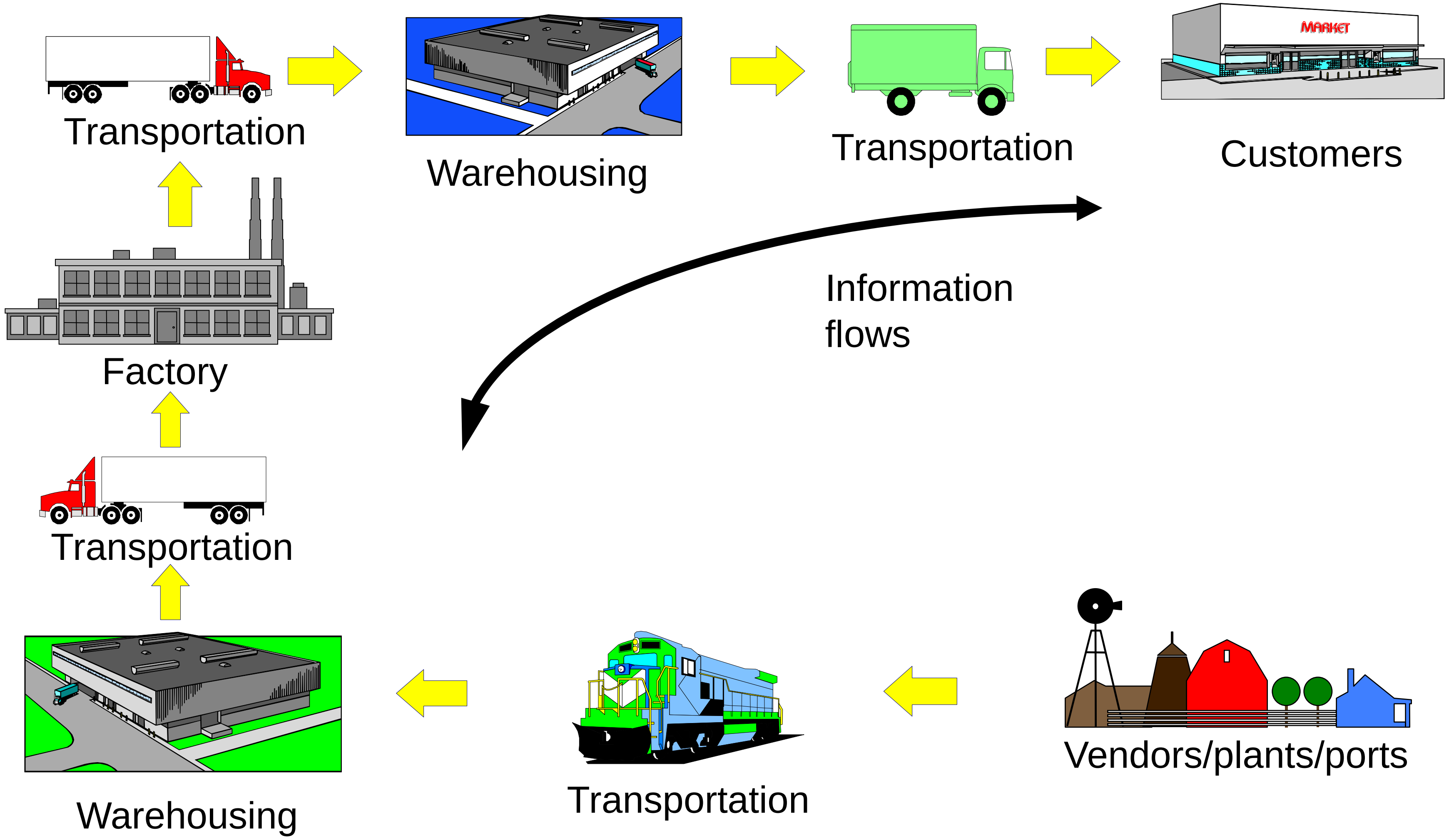
Time utility

Quantity utility

Cost utility of large-scale production

Logistics and Supply Chains – An Overview

Distribution Channel overview



Transportation Modes: Advantages and disadvantages

MODE	RELATIVE ADVANTAGES	RELATIVE DISADVANTAGES
Rail	• Full capability • Extensive routes • Low cost	• Some reliability, damage problems • Not always complete pickup and delivery • Sometimes slow
Truck	• Complete pickup and delivery • Extensive routes • Fairly fast	• Size and weight restrictions • Higher cost • More weather sensitive
Air	• Fast • Low damage • Frequent departures	• High cost • Limited capabilities
Pipeline	• Low cost • Very reliable • Frequent departures	• Limited routes (accessibility) • Slow
Water	• Low cost • Huge capacities	• Slow • Limited routes and schedules • More weather sensitive

Checklist for Choosing Transportation Modes

1. Speed
2. Dependability
3. Availability
4. Costs
5. Others

Shipping Transaction

- **Freight:** The transported material
- **Shipper / Consignor / (Freight) Originator:** The shipping party
- **Consignee / Freight Receiver:** The receiving party
- **Carrier:** The firm that provides the transportation service
- **Freight bill-of-lading (freight bill):** A document serving as a contract between the shipper and the carrier, specifying the obligations of both parties. In particular, it specifies:

https://www.youtube.com/watch?v=YVD4v-pIRdA

https://www.youtube.com/watch?v=ae9oVibkBZ4

Freight Types

- **Bulk cargo:** Cargo that is stowed loose on transportation vehicles, a tank or hold without any packaging; handled by pump, scoop, conveyor or shovel. Examples: grain, coal, petroleum and chemicals.
- **Break-bulk cargo:** Cargo in between bulk and containerized, that must be handled piece-by-piece by terminal workers; often stored in bags or boxes and stacked on **pallets**.
- **Containerized cargo:** Cargo filling an entire container that is handled as a single unit.
- **Container:** A single, rigid, sealed, reusable metal box in which freight is shipped by vessel, truck or rail. Usually 8x8 ft in width & height, 20 to 55 ft long. Some container types include: standard, high cube, hard top, open top, ventilated, insulated, refrigerated, etc.

Dunnage: Wood and packaging materials used to keep cargo in place inside a container or transportation vehicle.

https://www.youtube.com/watch?v=rJEz7jszEBI

Freight Units

- Freight is typically measured by **weight**:
  - Short ton (American) 2000 lbs
  - Long ton (English) 2240 lbs
  - Metric ton 2204.6 lbs (1000 kgs)
- or sometimes by **cube**, i.e., volume.

- Transportation equipment (vehicles, vessels, etc.) has pre-specified weight and volume capacities; e.g.,
  - **Deadweight:** The number of long tons that a vessel can transport of cargo, supplies and fuel.
  - **TEU (Twenty-foot Equivalent Unit):** Method for specifying a vessel load or capacity in units of containers that are 20ft long. (e.g., a 3000 TEU vessel can accommodate - at most - 1500 numbers of 40ft containers).
  - **FEU (Forty-foot Equivalent Unit)**
  - **Slot:** A place for a container onboard a container ship (typically, one TEU).

Carrier Types

- **Private carrier:** Owned and operated by a shipper. Usually refers to private trucking fleets. More advantageous solution for high density / short distance or special-need shipments.(e.g., Safeway)

- **Common carrier:** A for-hire carrier providing services to general public.

Carrier Types *(Continued…)*

- Parcel / express carriers (UPS, FedEx, TNT, DHL)
- LTL (Less Than Truckload) Trucking (Yellow, Consolidated Freightways)
- LCL (Less than Container Load) https://www.youtube.com/watch?v=C0J4AlMmelg
- FTL (Full Truck Load) trucking (Hunt, Schneider)
- CL (Container Load)
- Rail carrier (Norfolk Southern)
- Air carriers (Delta, Flying Tigers)
- Ocean carrier (SeaLand, American President Lines)
  - Liner Shipping: vessels sailing between ports on regular schedule, which is published and available to public.
  - Tramp shipping: Vessels calling at different ports upon availability of cargo (used primarily for bulk shipping)
- Pipeline

Mediators and Integrators

- **Freight forwarder:** An agency that receives freight from the shipper and then arranges for transportation with one or more carriers for transport to the consignee. Typically, consolidates freight from many shippers to obtain better rates. Also, often provide pickup and delivery services, as well as other shipping services: packaging, temporary storage, customs clearing.
- **Transportation Broker:** An agency that obtains negotiated large-volume transportation rates from carriers and resells this capacity to shippers. No additional services are provided, though.
- **NVOCC (Non Vessel-Operating Common Carrier):** Owns no vessels, but provides ocean shipping freight-forwarding services.
- **Shipper's Association:** Not-for-profit association of shippers using collective bargaining and freight consolidation to obtain lower, high-volume transportation rates. Avoids premium charge paid to forwarders. Only non-competitive shippers may associate, due to monopoly restrictions.
- **3PL:** A third-party, or contract, logistics company, used to outsource logistics services. It can also handle: Purchasing, Inventory management/warehousing, transportation and order management (e.g., Schneider Logistics, Ryder Logistics, UPS Logistics)

- **Integrators:** Companies providing door-to-door domestic and international air- freight service. Owns and operate aircraft as well as ground delivery fleet of trucks (e.g., UPS, FedEx, Emery Worldwide).

Transportation Systems

- **Direct Shipping:** Shipment travels directly from consignor to consignee. Used primarily for TL shipping.

- **Dead-head:** A portion of a transportation trip in which no freight is conveyed – an empty move.

- **Hub-and-spoke:** Large hub terminals are employed for freight consolidation. Medium-volume services are used for spoke-to-hub collection and hub-to-spoke distribution. Air freight, parcel shipping, LTL and, more recently, ocean shipping is organized in this manner.
- **Pickup and delivery (cartage):** Local hauling of freight
- **Longhaul (or Linehaul):** Terminal-to-terminal freight movements
- **Milk runs:** A vehicle route in which a truck delivers (picks up) freight from (for) a single terminal to (from) a number of consignees.
- **Interline / Intermodal shipment:** Shipment employing more than one carrier / transportation mode.

Charging Patterns for Common Carriers

- **Related to shipment size**
  - **LTL and LCL shipments**: Minimum total rate for quantities below a minimum threshold, then several weight categories with different rates.
  - **TL and CL shipments**: Rate depends only on equipment size ordered.
  - **Time-volume rates**: Encourages shippers to send minimum quantities regularly, in an effort by carriers to ensure regular flow of business.

Charging Patterns for Common Carriers *(Continued…)*

- **Related to distance**
  - **Uniform rates:** Independent of distance (e.g., USPS priority mail)
  - **Proportional rates:** Fixed rate + variable rate per distance (truckload rates)
  - **Tapered rates:** Increase with distance but at decreasing rate (air transportation)
  - **Blanket rates:** Constant rates for certain intervals of distance (e.g., UPS rates, bulk cargo).

Factors affecting the choice of Mode and Carrier

- Door-to-door cost
- Loss and damage: likelihood
- Loss and damage: claims handling
- Transit time reliability
- Rate negotiation experiences
- Shipment tracking / tracing
- Door-to-door transit time
- Pickup / delivery service quality
- Single-line service availability (no interlines)
- Equipment availability

Motor Carrier

The Development of the Motor Carrier Industry

Images courtesy of Forbes

- Started around World War I, when converted automobiles were used for pickup and delivery in local areas.
- The interstate system of highways developed from the 1950s to 1991.
- Motor carriers steadily replaced railroads as the mode of choice for freight transportation.
- Dominant mode of freight transportation today.

Types of Motor Carriers

- Motor Carrier Industry
  - For-Hire
    - Local
      - Exempt
    - Intercity
      - Common
      - Contract
      - Exempt
  - Private

Types of Motor Carriers

For-hire vs. Private Carriers

For-hire Carriers

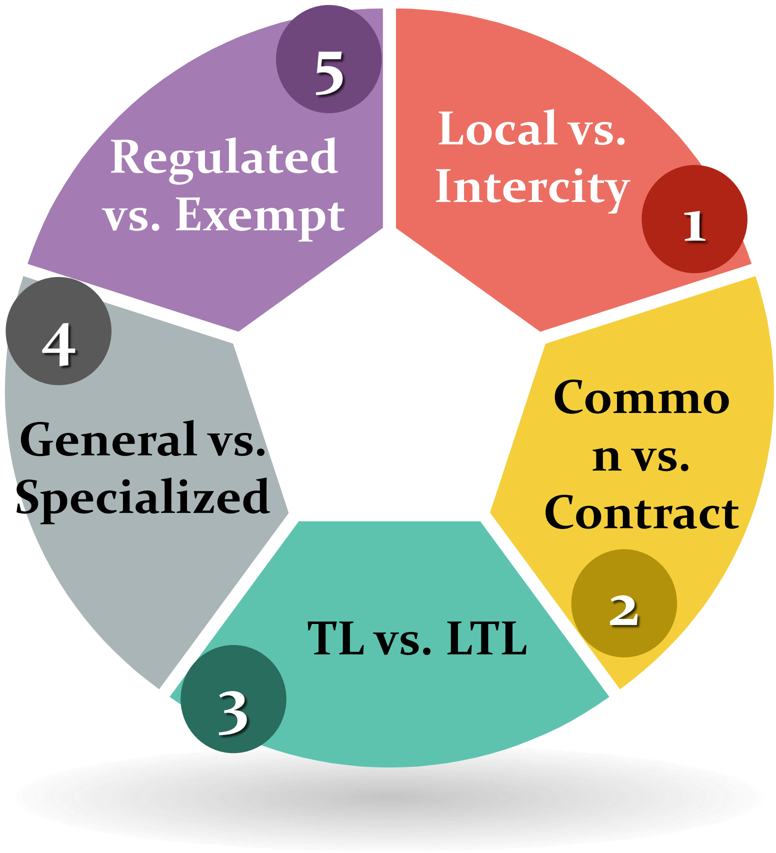
* Provide services to the public.
* Charge a fee for the service.

Private Carriers

* Provide a service to the industry or company that owns or leases the vehicles.
* Do not charge a fee, but incur cost.
* Transport commodities for hire as exempt for-hire carriers.

Types of Motor Carriers

Classification of For-hire Carriers

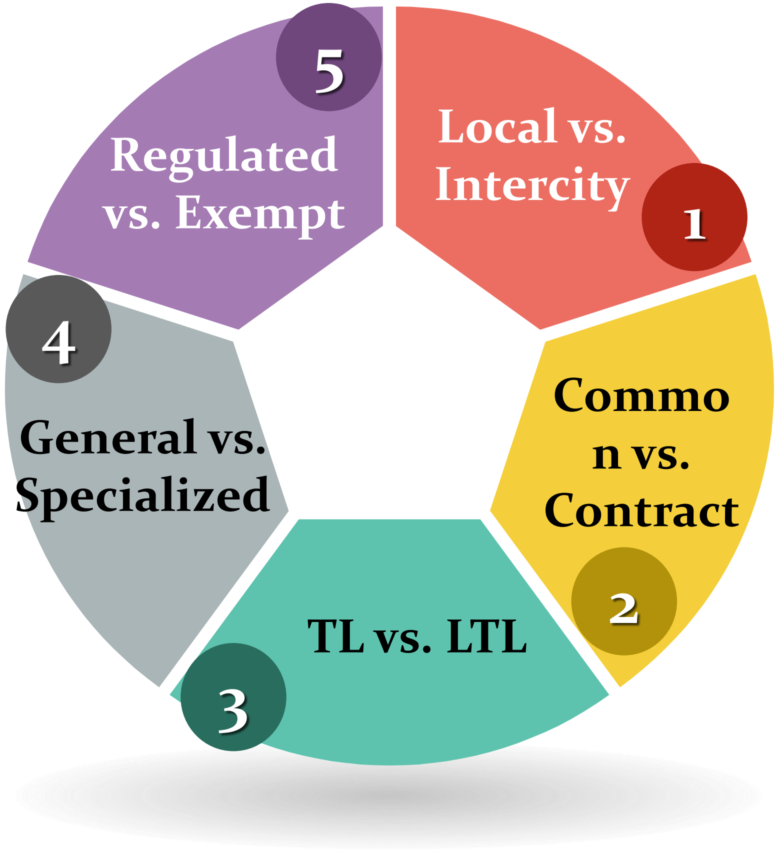


1

- Local carriers pick up and deliver freight within the commercial zone of a city.
- Intercity carriers operate between specifically defined commercial zones.
- Local carriers and intercity carriers often work in conjunction.

Types of Motor Carriers

Classification of For-hire Carriers *(continued)*

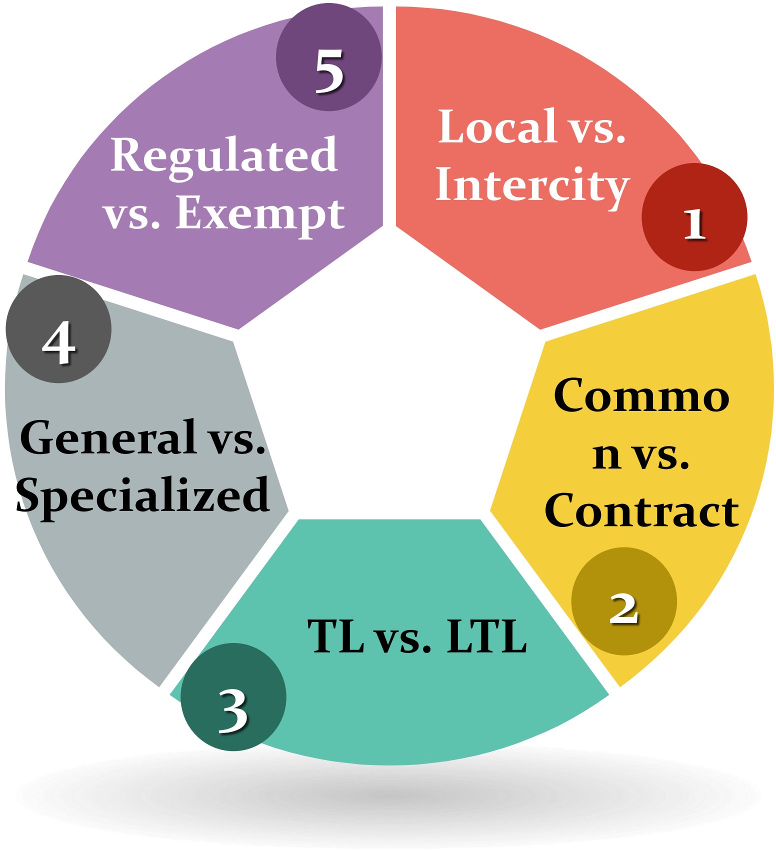


2

- Common carriers are required to serve the general public upon demand, at reasonable rates, and without discrimination.
  - Further classified by the type of commodity authorized to haul
- Contract carriers serve specific shippers with whom the carriers have a continuing contract.
  - Dedicated carriage over "dedicated" regular routes

Types of Motor Carriers

Classification of For-hire Carriers *(continued)*

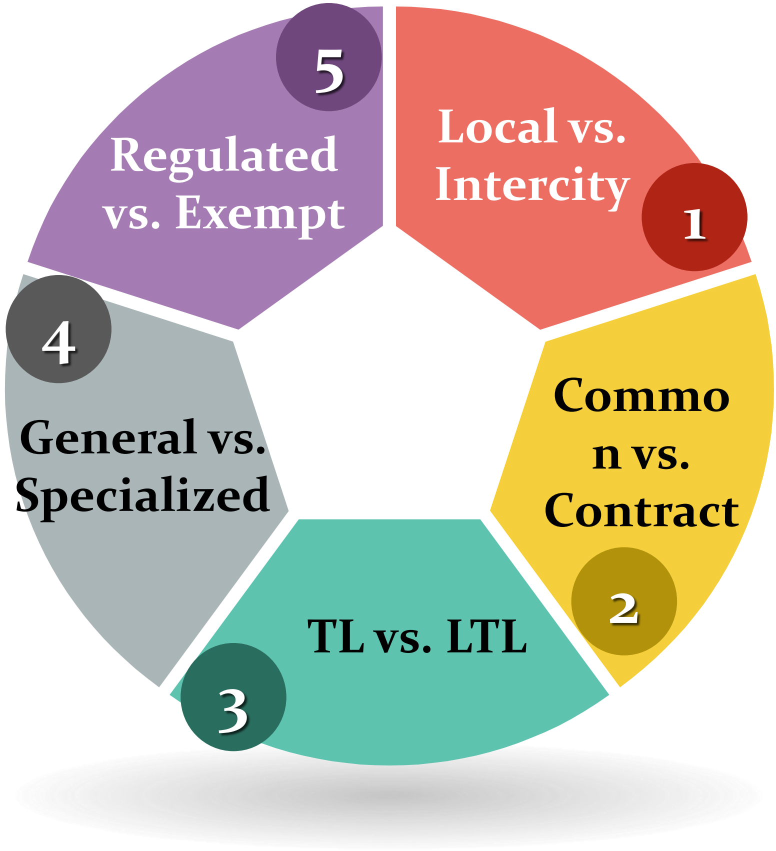


3

* TL carriers provide service to shippers who tender sufficient volume to meet the minimum weights required for a truckload shipment.
* LTL carriers provide service to shippers who tender shipments lower than the minimum truckload quantities
  * "Heavy LTL" motor carriers (upper end of LTL shipments)

Types of Motor Carriers

Classification of For-hire Carriers *(continued)*

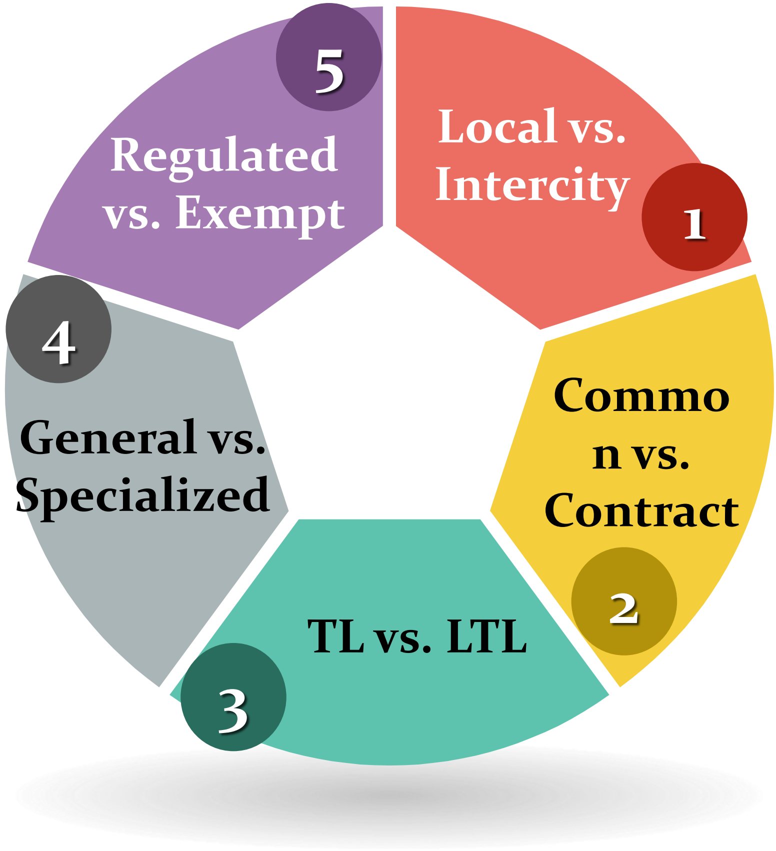


4

* Specialized motor carriers haul a special commodity such as:
  - Odd-sized and/or heavy freight
  - Liquids products
  - Freight requiring controlled temperature
  - Hazardous materials

Types of Motor Carriers

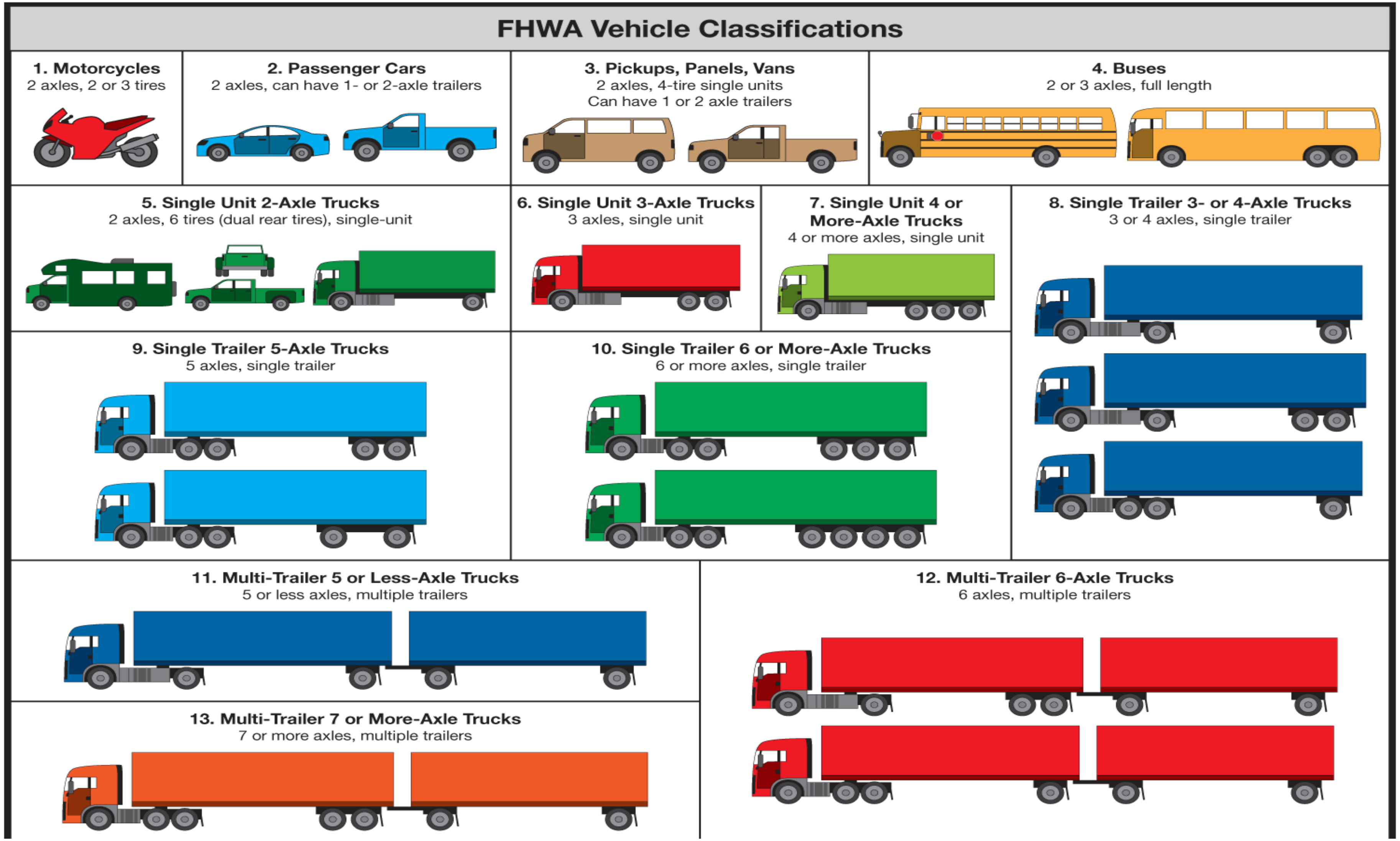
Classification of For-hire Carriers *(continued)*



5

- An exempt for-hire motor carrier transports exempt (unregulated) commodities owned by others for compensation.
- The exempt commodities usually include unprocessed or unmanufactured goods, fruits and vegetables, and other items of little or no value.

Source: Federal Motor Carrier Safety Administration


FHWA Vehicle Classifications
1. Motorcycles
2 axles, 2 or 3 tires
2. Passenger Cars
2 axles, can have 1- or 2-axle trailers
3. Pickups, Panels, Vans
2 axles, 4-tire single units
Can have 1 or 2 axle trailers
4. Buses
2 or 3 axles, full length
5. Single Unit 2-Axle Trucks
2 axles, 6 tires (dual rear tires), single-unit
6. Single Unit 3-Axle Trucks
3 axles, single unit
7. Single Unit 4 or More-Axle Trucks
4 or more axles, single unit
8. Single Trailer 3- or 4-Axle Trucks
3 or 4 axles, single trailer
9. Single Trailer 5-Axle Trucks
5 axles, single trailer
10. Single Trailer 6 or More-Axle Trucks
6 or more axles, single trailer
11. Multi-Trailer 5 or Less-Axle Trucks
5 or less axles, multiple trailers
12. Multi-Trailer 6-Axle Trucks
6 axles, multiple trailers
13. Multi-Trailer 7 or More-Axle Trucks
7 or more axles, multiple trailers

Operating and Service Characteristics:

Special vehicles designed to meet special shipper needs.

Dry van: Standard trailer or straight truck with all sides enclosed.

Tank trailer: Used to haul liquids like petroleum products.

Open top: Trailer top is open to permit loading through the top.

Refrigerated vehicles: Cargo unit has controlled temperature.

Flatbed: Trailer has no top or sides, used extensively to haul steel.

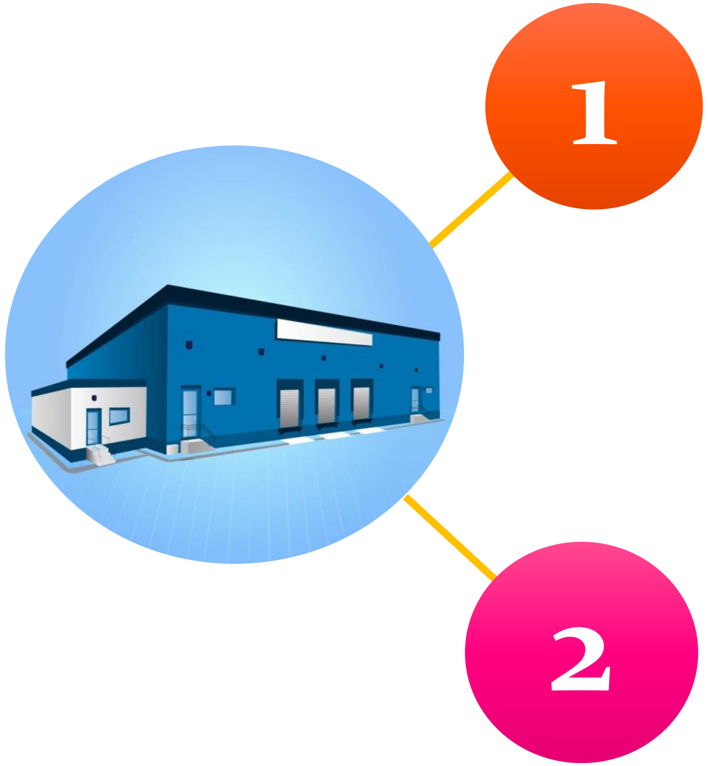
High cube: Cargo unit is higher than normal to increase cubic capacity.

Operating and Service Characteristics:

Terminals

- **Pickup and Delivery Terminals** (PUD), also called satellite or end-of-the-line (EOL) terminals, most commonly found in the LTL hub-and-spoke system .
- **Break-bulk Terminals,** commonly found in the LTL hub-and-spoke system .
- **Relay Terminals** necessitated by the maximum hours of service regulation that is imposed on drivers.

Operating and Service Characteristics:
Terminal Management Decisions



- **Number of Terminals**
  - The degree of market penetration and customer service desired
  - Terminal size vs. peddle run distance tradeoffs
- **Location of Terminals**
  - Hours-of-service regulation
  - Consideration of backhauls between terminals
  - Market penetration and customer service desired

Current Issues

1. Safety
2. Technology
3. LTL Rates
4. Financial Stability

Railroad

Development of the US Railroad Industry

Images courtesy of pixgood.com

- Dominant mode from 1850s to World War II, playing a pivotal role in US economic development

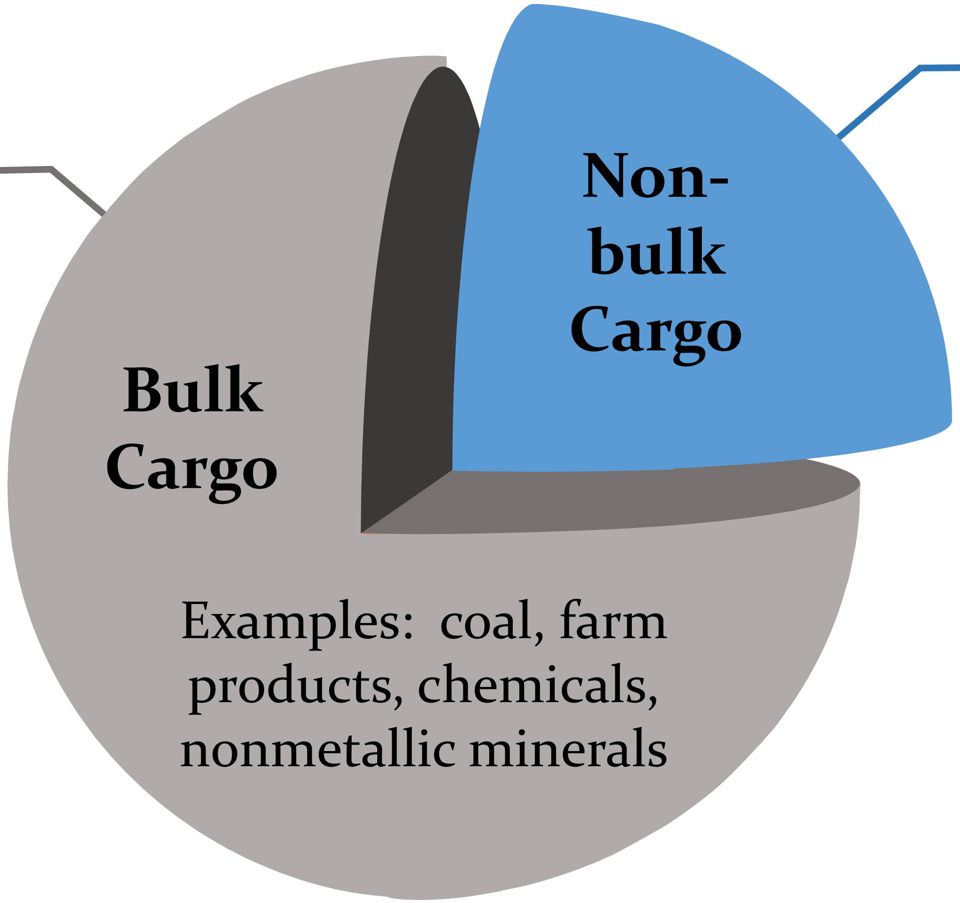
- Domination begins to wane after 1920 due to:
  * Public funding for roads, inland waterways, and air transport
  * Changes in economy and shipper service-related needs
  * Financial plight and economic regulation

- Improved price and service competitiveness after economic deregulation (The Staggers Rail Act), continuing to be a vital part of US economy today

Operating and Service Characteristics

Commodities Hauled

More than 74 percent of total rail carloadings in 2012 involved the movement of bulk materials.



Notable trend toward movements of intermodal containers and trailers, carrying high-value finished products.

Operating and Service Characteristics

Constraints and Strengths

Strengths

* Large carrying capacity (few size or weight constraints).
* Capable of handling almost any type of cargo.
* Railroads assume liability for loss & damage.

Constraints

* Fixed rights-of-way impedes door-to-door service.
* Through service prone to delays in delivery.
* Relatively high percentage of goods damaged in transit.

Operating and Service Characteristics

Equipment – Types of Rail Car

Boxcar: Standardized roofed freight car with sliding doors on the side used for general commodities (plain); can be specially modified (equipped) for specialized merchandise, such as automobile parts.

Hopper car: A freight car with the floor sloping to one or more hinged doors used for discharging bulk materials.

Covered hopper: A hopper car with a roof designed to transport bulk commodities that need protection from the elements.

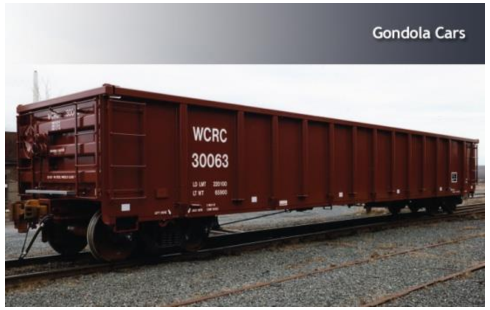
Images courtesy of Greenbrier Companies, justrains.com, and Greenbrier Companies

Operating and Service Characteristics

Equipment – Types of Rail Car *(continued)*

Flatcar: A freight car with no top or sides used primarily for TOFC service, and movements of machinery and building materials.

Refrigerated car: A freight car with refrigeration equipment for temperature control.



Gondola: A freight car with a flat bottom, fixed sides, and no top used primarily for hauling bulk commodities.

Tank car: Specialized car used for the transport of liquids and gases

Images courtesy of Pacific Western Rail System, tunaruna.com, Greenbrier Companies

Operating and Service Characteristics

Intermodal (Piggyback) Services

TOFC

Trailer on Flatcar

* Transports highway trailers on railroad flatcars.
* Combines line-haul efficiencies of rail with the flexibility of motor transport.
* On-time deliveries, regularly scheduled departures, and fuel efficiency major reasons for growth.

COFC

Container on Flatcar

* Transports shipping containers on railroad flatcars.
* Land-bridge operations key component of international trade.
* Double-stack container trains greatly improves rail equipment and train productivity.

Airlines

Development of the Airline Industry

Images courtesy of imgkid.com

- In 1903, Wilbur and Orville Wright made their first flight and sold their invention to the federal government.
- In 1908 the development of air transportation began. The use of airplanes for mail transport marked the beginning of the modern airline industry.
- Today, airline travel is a common form of transportation for long-distance passenger and freight travel, especially when time is of the essence.

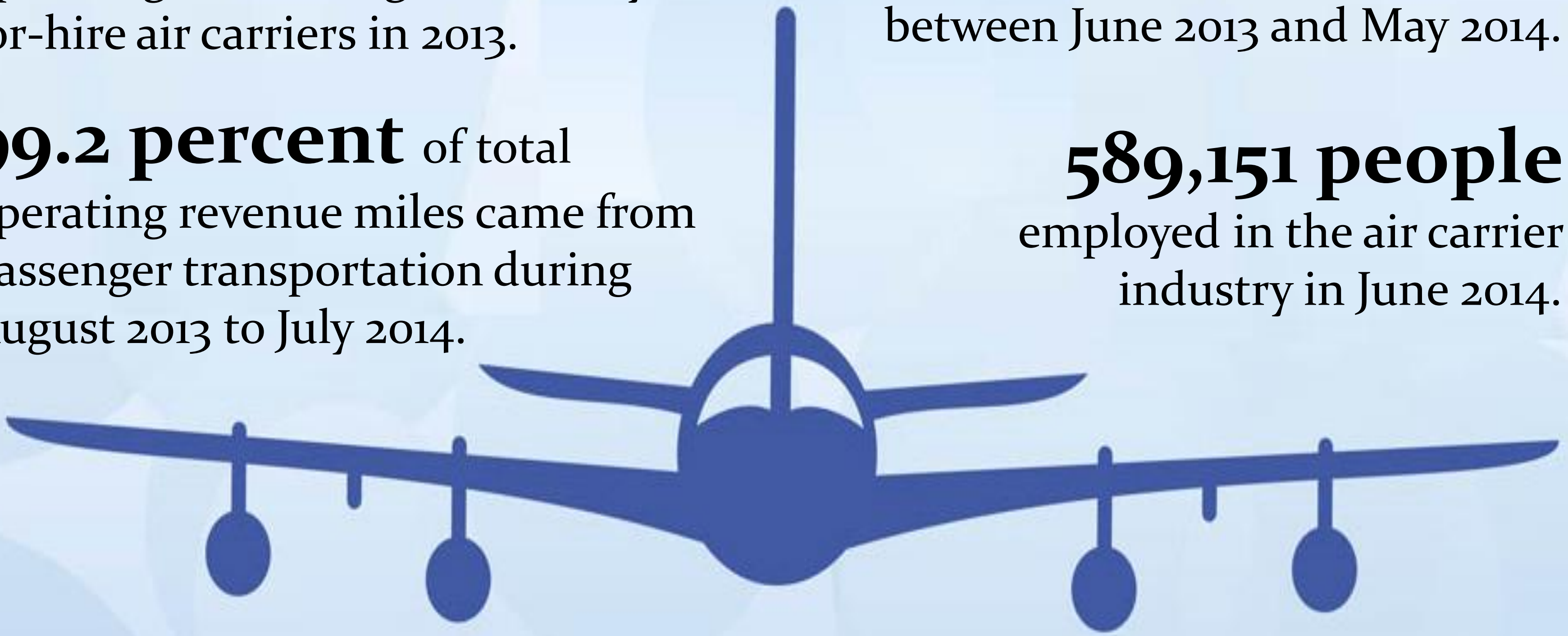
Significance of the Airline Industry

$199.7 billion of operating revenues generated by for-hire air carriers in 2013.

93.1 billion revenue ton-miles transported by air carriers between June 2013 and May 2014.

99.2 percent of total operating revenue miles came from passenger transportation during August 2013 to July 2014.

589,151 people employed in the air carrier industry in June 2014.



Operating and Service Characteristics
Constraints and Strengths

Strengths

- High terminal-to-terminal speed
- Reliability (low transit time variation)
- Low rates of damages

Constraints

- Limited accessibility.
- Reduced frequency of flights.
- High service rates.
- Added access and terminal time and cost significant for short distances (under 800 miles).

Operating and Service Characteristics

Equipment – Types of Aircrafts

There are several different sizes of airplanes in use, from small commuter planes to huge, wide-body, four-engine planes used by the nationals.

Example: Delta Airlines Fleet

Operating and Service Characteristics

Terminals (Airports)

- Government (state and local) invest and operate airports and airways.
- Certain airports in the carriers' scope of operation become hubs, similar to the motor carrier's break-bulk terminal.
- Air carriers pay for the use of the airport through:
  - Landing fees
  - Rent and lease payments for space
  - Taxes on fuel and airline tickets
  - Aircraft registration taxes

Images courtesy of Passenger Terminal Today.com

* Airport terminals provide services to passengers, such as restaurants, banking centers, souvenir and gift shops, and snack bars.
* Users pay a tax on airline tickets and air freight charges.

Water Transportation

Development of Water Transportation

Images courtesy of pixshark.com

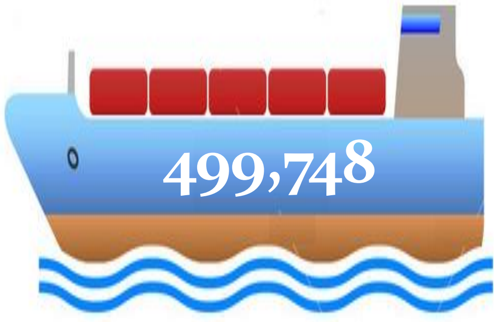
- The first principle form of long distance freight and people transport, played an important role in the early development of the United States and settlements.
- Continued to be the most important and efficient form of transportation available until the railroads were developed in the mid-18th century.
- Today, water transport remains viable for the movement of basic raw materials, and plays a primary role in global commerce transportation.

Significance of Water Transportation

The relative importance of water carriers' in the US transportation system declined somewhat over the past decade due to shift from manufacturing-to a service-based economy, and a supply chain emphasis on speed.

Short tons carried by domestic water carriers in 2012.

Of the total expenditures of for-hire transportation included in GDP was accounted for by water carriers.



Ton-miles of total US freight carried by domestic water carriers in 2011.

People employed for water transportation in 2010.

Operating and Service Characteristics

Constraints and Strengths

Strengths

* Low cost transport service for large volumes over medium to long distances
* Relatively large carrying capacity
* Fuel efficient

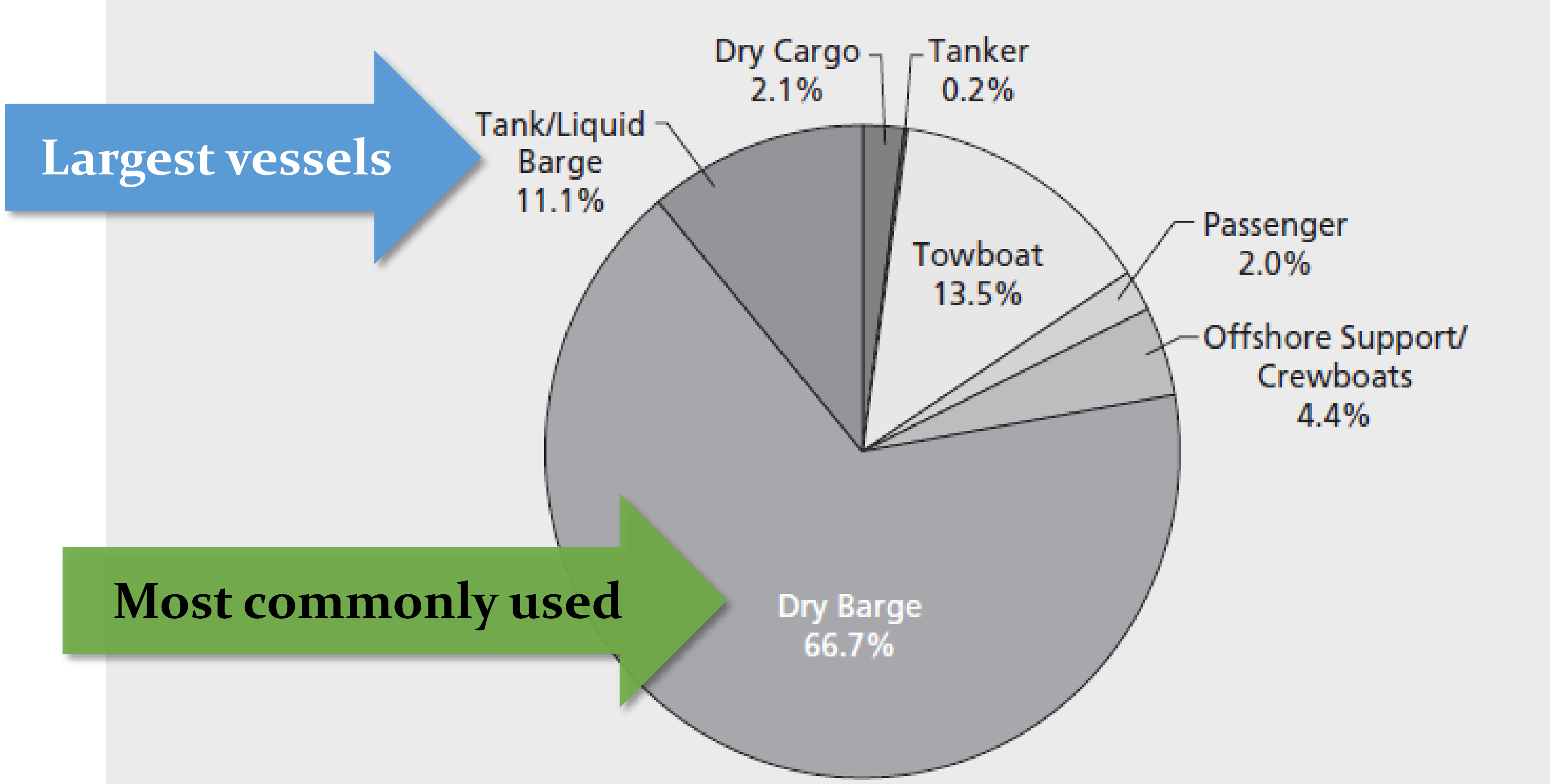
Constraints

* Speed of service (slowest mode for dry cargoes)
* Vulnerable to ice, flood, and drought conditions
* Accessibility limitations
* Packaging requirements for high-value goods

Operating and Service Characteristics

Types of Vessels

FIGURE 8-2 U.S. Flag Vessels by Type



Development of Pipeline Industry

Images courtesy of Hi-tech Online

- In 19th century, pipelines were originally used to feed other modes of transportation, e.g. railroads or water.
- In early 20th century, most pipelines were owned by large oil companies that often used them to control the oil industry.
- After WWII, pipelines were ordered to operate as common carriers (the Champlin Oil Case)

Significance of Pipelines

21 percent of total US freight ton-miles was moved via pipelines in 2009.

910 billion ton-miles of US freight were moved via pipelines in 2009.

4 percent of the total intercity transportation revenues earned by pipelines in 2012.

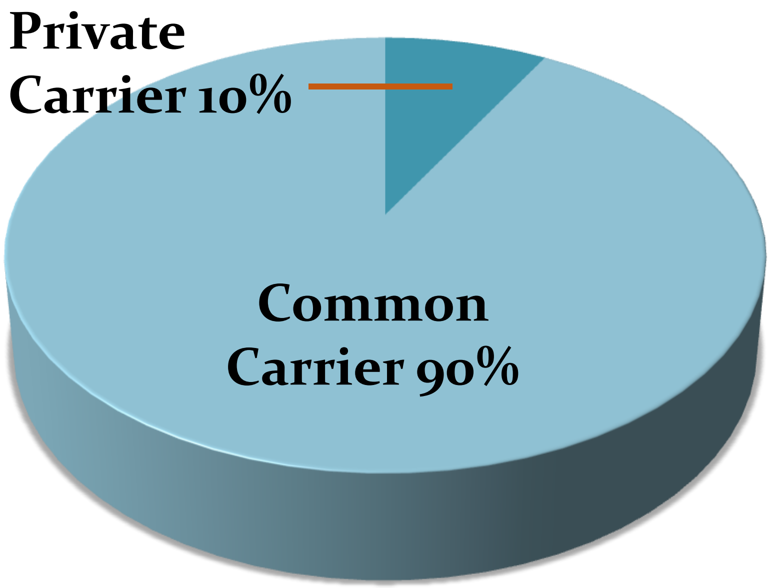
152,000 miles of oil pipelines in 2012

1,566,000 miles of natural gas pipelines in 2012

Overview of the Pipeline Industry

Ownerships and Type of Carriers

The for-hire carriers dominate the pipeline industry.

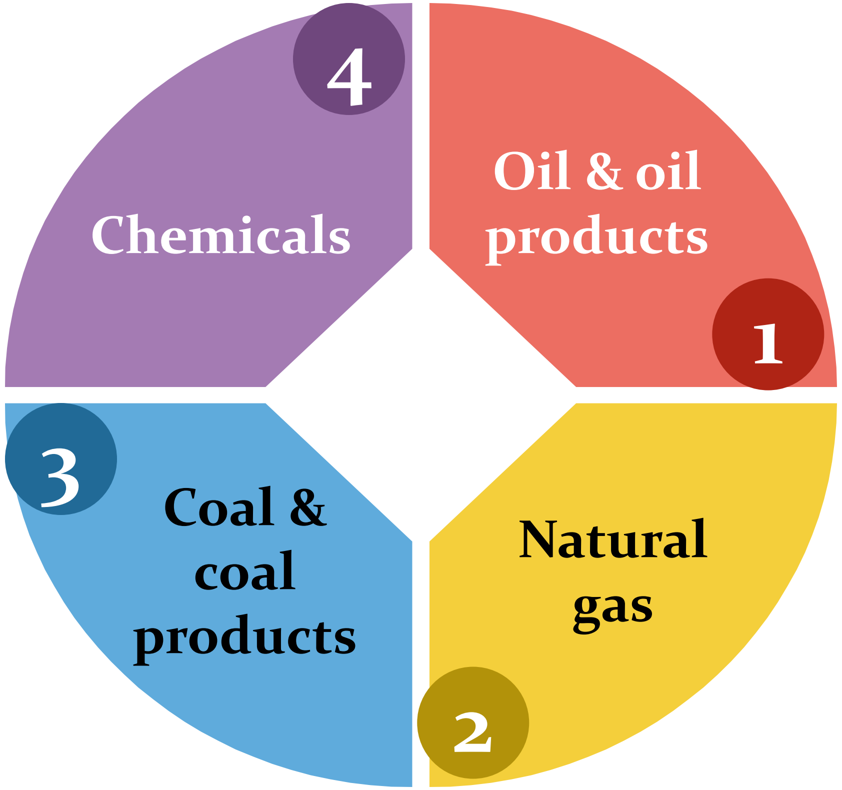


Owners of pipelines

- Individual, vertically integrated oil companies.
- Jointly owned pipeline companies.
- Others
    - Railroads
    - Independent oil companies
    - Other industrial companies

Operating and Service Characteristics

Commodities Hauled



- Pipelines are limited in the markets they serve and commodities they can haul.
- Pipelines are the only mode that are unidirectional with no backhaul.

Operating and Service Characteristics

Constraints and Strengths

Strengths

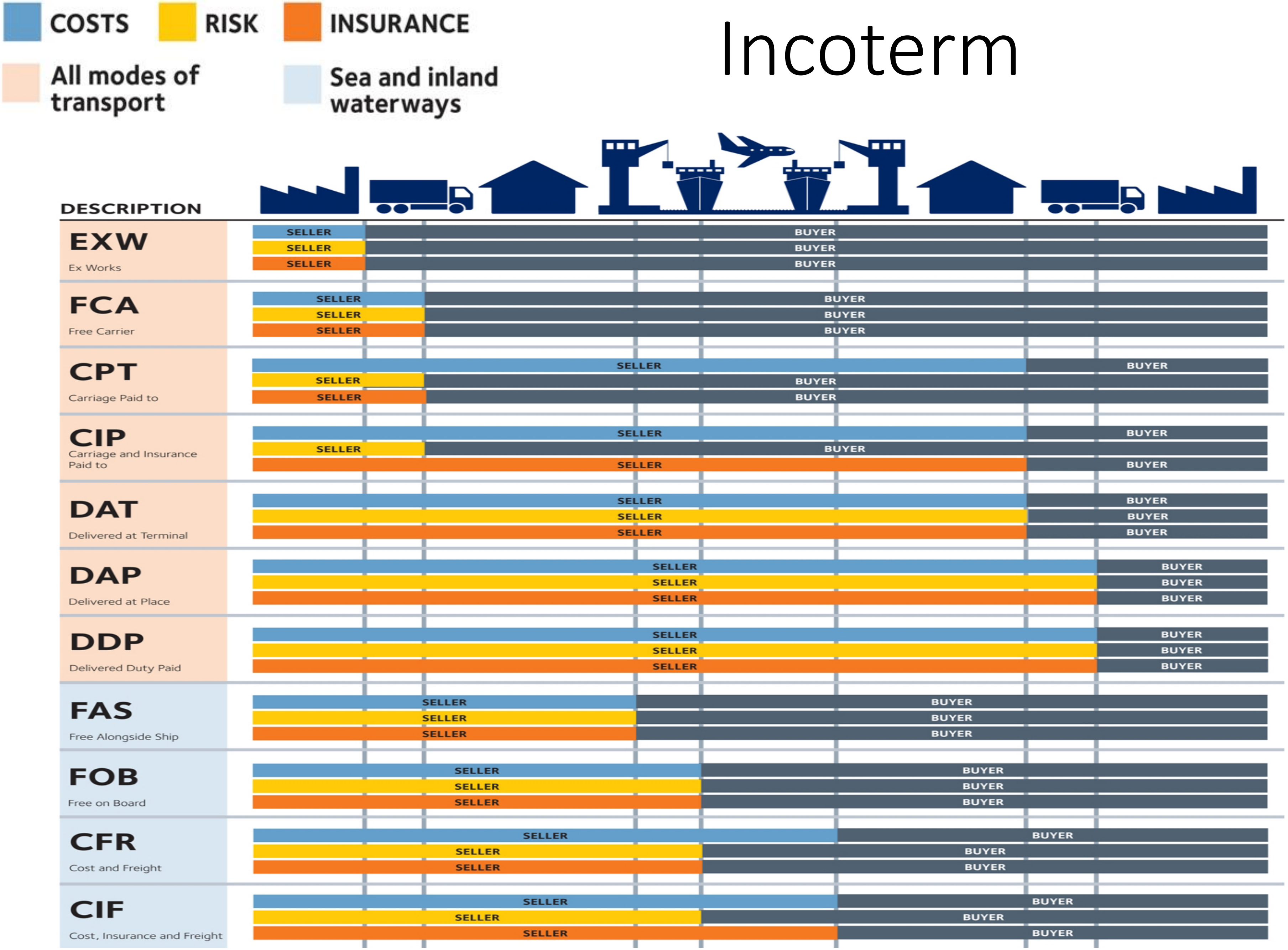
* Low service rates
* Low loss and damage rates
* Warehousing function (3-5 mph)
* High delivery dependability

Constraints

* Limited responsiveness due to slow speed
* Limited geographic flexibility
* Limited variety of products carried

https://www.youtube.com/watch?v=wgHqzv-Pxss
https://www.youtube.com/watch?v=MXUFGbnqYm8
https://www.youtube.com/watch?v=VueHMW4Wrn4

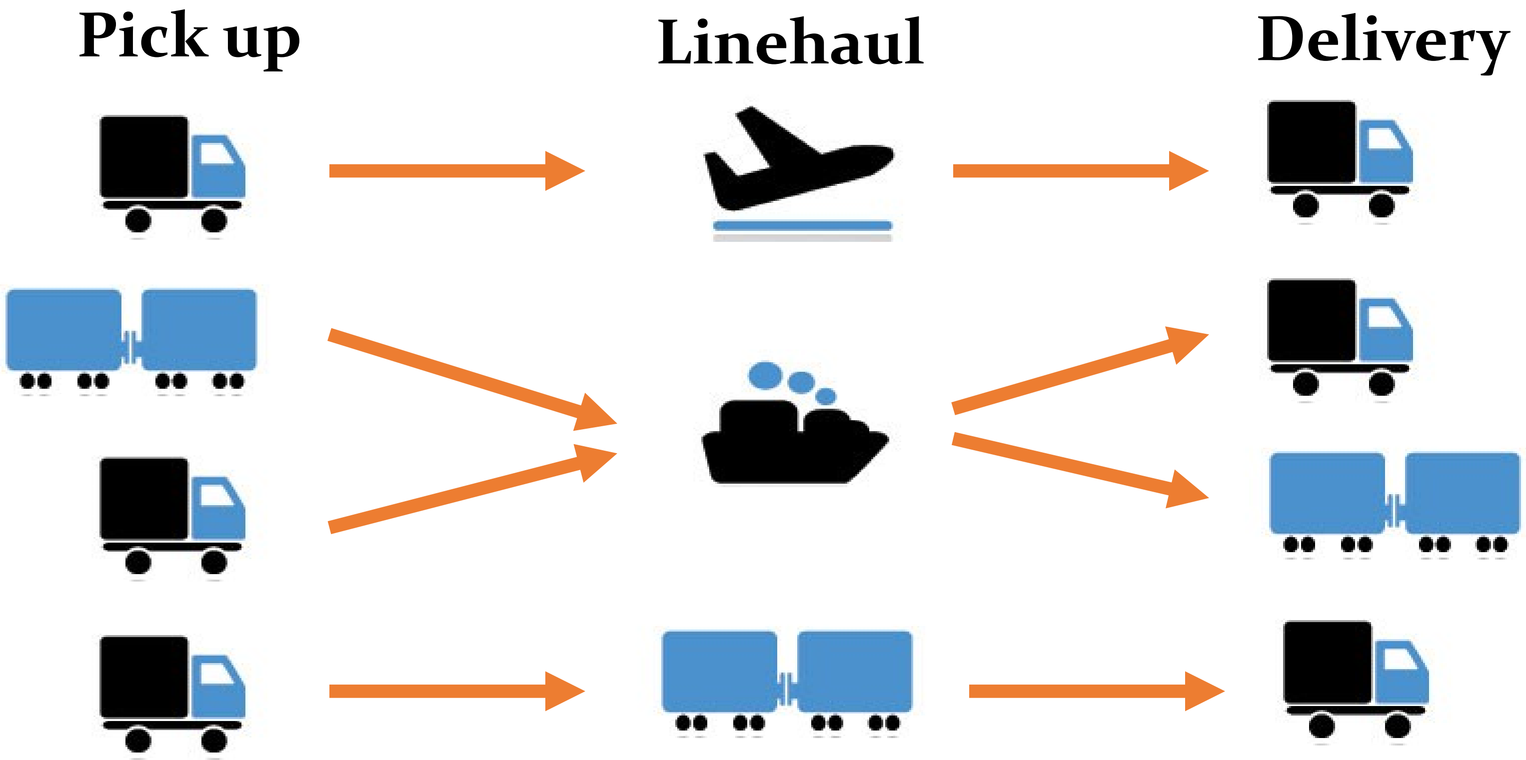
Incoterm



Images courtesy of NDF Freight Forwarding Ltd

Intermodal Transportation Options

Carrier, rather than shipper, typically makes decisions of which combination to use.



Standard Dry Cargo Containers

DRY CARGO CONTAINERS

• DIMENSIONS

Type	Container Weight			Interior Measurement				Door Open	
	Gross (kg)	Tare (kg)	Net (kg)	Length (m)	Width (m)	Height (m)	Capacity (m^3)	Width (m)	Height (m)
20 ft	24,000	2,370	21,630	5.898	2.352	2.394	33.20	2.343	2.280
40 ft	30,480	4,000	26,480	12.031	2.352	2.394	67.74	2.343	2.280

HIGH CUBE CONTAINERS

• DIMENSIONS

Type	Container Weight			Interior Measurement				Door Open	
	Gross (kg)	Tare (kg)	Net (kg)	Length (m)	Width (m)	Height (m)	Capacity (m^3)	Width (m)	Height (m)
40 ft	30,480	3,980	26,500	12.031	2.352	2.698	76.30	2.340	2.585
45 ft	30,480	4,800	25,680	13.544	2.352	2.698	86.00	2.340	2.585

Intercontinental Transportation
Ocean Shipping

Service Options

Liner

- Serve a particular trade area, such as the trans-Pacific lanes, trans-Atlantic lanes, or Asia-Europe lanes.
- Some liner ships travel on “round the world” schedules.

Charter

- Operate in geographic regions defined by the individual customer
- Charter types include voyage charter, time charter, demise charter (including bareboat charter)

Private

- Private ships are owned or leased on a long-term basis by the company moving the goods.

Intercontinental Transportation

Ocean Shipping – Equipment Types

There were 47,547 cargo ships in the world fleet (2013). Most ships fly a flag of convenience.

- Containerships (box ships)
- Break-bulk ships
- Roll-on/roll-off (RORO)
- Bulk carriers
- Combination ships

Images courtesy of Beach Area

Intercontinental Transportation

Ocean Shipping – Current Issues

Ultra-large containerships (ULCS)

* **Limits of potential routes.** Few ports can handle ships of this length & draught.
* **Port congestion.** Added amount of time required to load/offload containers.
* **Load factors.** High load factors required.

Ocean carrier alliance

* Originally conceived as a competitive tool to provide more frequent service & better reliability.
* Today, used as a defensive response to prolonged overcapacity & faltering freight rates

E-shipping-enabled processes

* Shifts from inefficient, error-prone manual processes to process automation

Intercontinental Transportation

International Air

Service Options

Combination Carriers

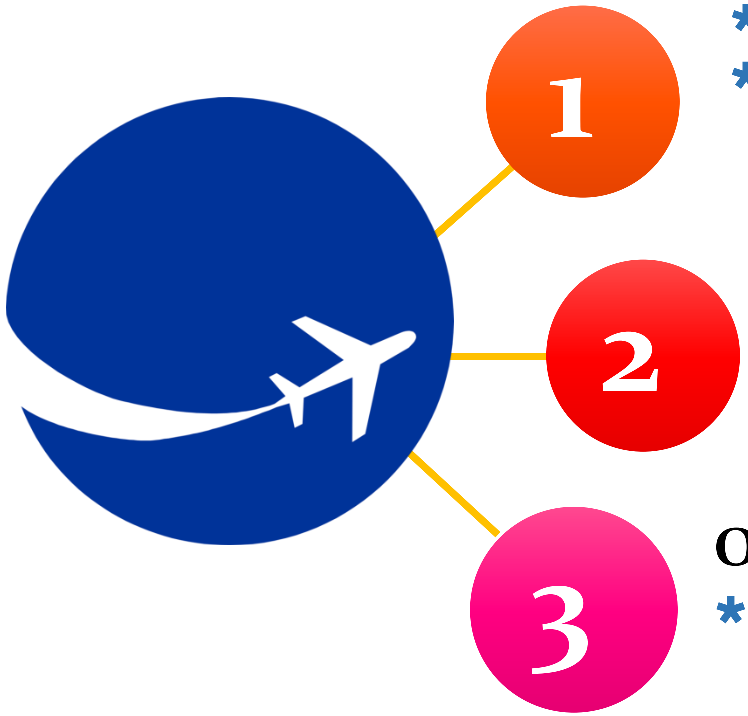
- Move freight and passengers, with cargo loaded in the belly of the aircraft.

Air Cargo Carriers

- Focus exclusively on the movement of freight, packages, letters, and envelopes.
- Provide scheduled service (majority) or on-demand charter service
- Integrated carriers offer door-to-door service e.g. FedEx and UPS
- Nonintegrated carriers offer airport-to-airport service e.g. Cargolux and AirBridgeCargo

Intercontinental Transportation

International Air – Equipment Types



Air freighters

- Aircrafts dedicated solely to freight movement
- Carry palletized or containerized cargo called unit load devices (ULDs).

Passenger airplanes

- Passengers travel on main deck/cabin, luggage and some cargo loaded into lower deck/belly
- Commonly restricted to smaller individual shipments of cargo

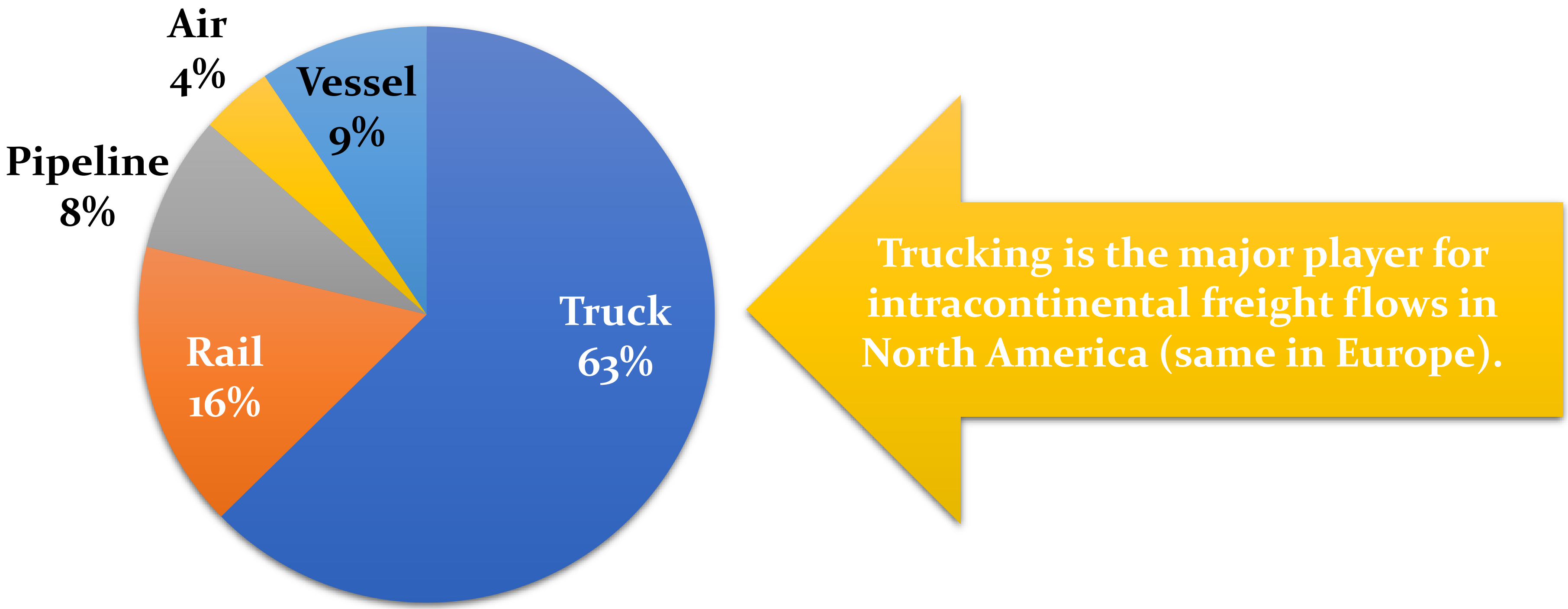
Ombi airplane

- Aircrafts with the flexibility to change the passenger/cargo mix on the main deck of the aircraft

Images courtesy of Galleryhip

Intracontinental Transportation
Trucking

US-NAFTA Merchandise Trade Value by Mode: 2013



Source: US Bureau of Transportation Statistics

Intracontinental Transportation

Trucking – Current Issues

A patchwork of domestic rules and regulations impede international freight flows.

Images courtesy of Forbes

- Few global standards for trucking or roadway infrastructure. Different regulations regarding equipment length, width, and carrying capacity.
- Inconsistent safety regulations regarding driver hours of service, speed limits, and inspections.
- Driving bans during certain times of the day and/or days of the week in some countries.

Intracontinental Transportation

Railroads

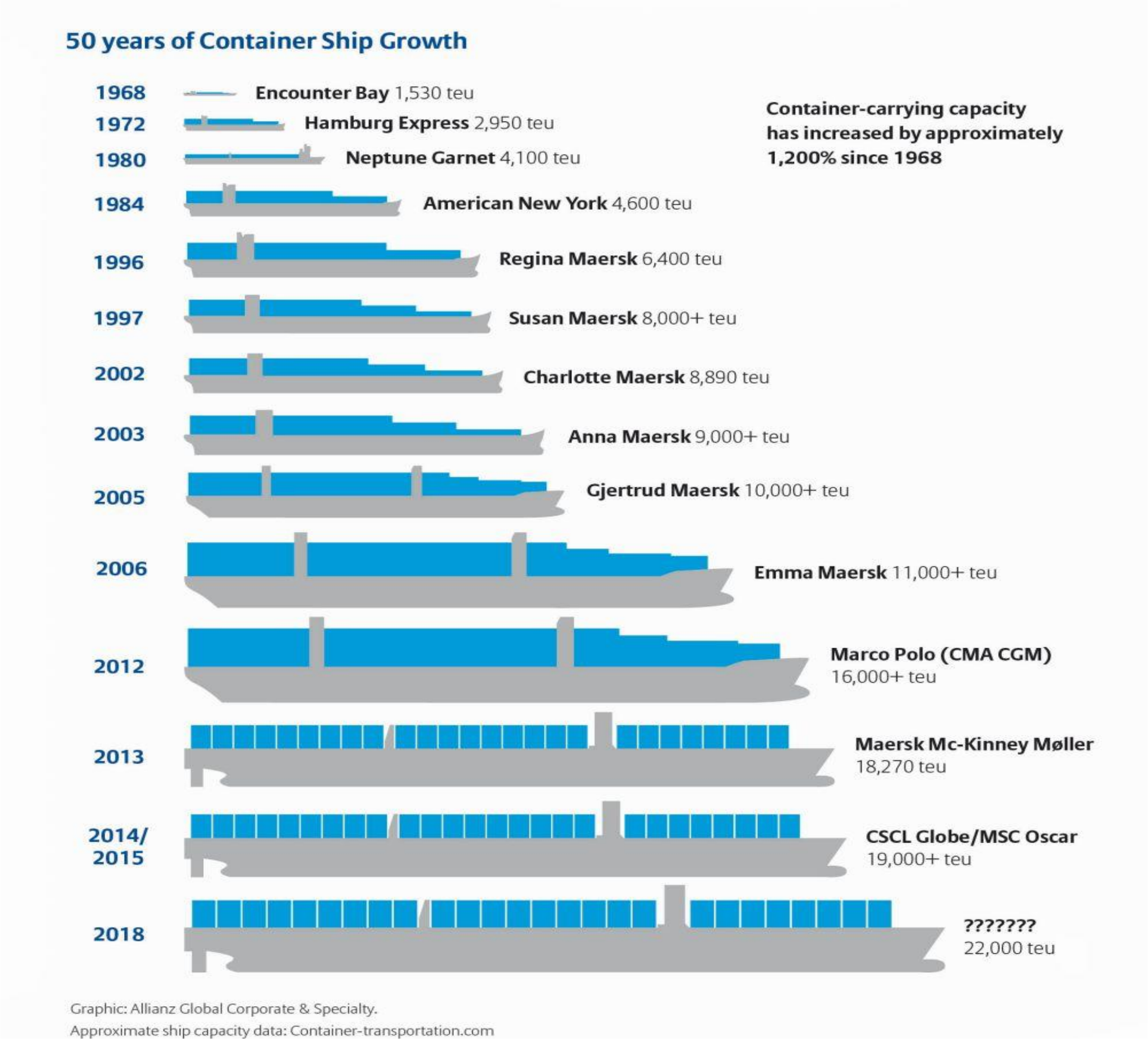
Images courtesy of pixgood.com

- International rail service benefits from a standardized infrastructure and equipment.
- Still, North American rail traffic accounts for only 15 percent of the total regional freight volume.
- Rail activity mainly focuses on the movement of bulk raw materials and intermodal containers.

International Gateways
Seaports

International Gateways

Seaports – Current Issues



- Increasing size of containerships
  - Deeper waterways
  - Larger cranes
  - Sailing schedules to accommodate the longer unloading and processing times
- Congestion at major seaports
- Periodic labor disputes and protracted labor contract negotiations

Custom Clearance

Customs Broker

Customs brokers are private individuals or firms licensed by the CBP to act as agents for importers, providing expertise in the entry process for a fee.

Prepare and file the necessary Customs entry documents

Arrange for the payment of duties

Speed the release of the goods in CBP custody

Coordinate inland and ocean transport

Dockside-inspect cargo

Drivers of Carbon Emissions and Reduction Potentials

Part of supply chain	Driver of emissions	Ways to reduce emissions (examples)
Ocean transportation	• Volume moved • km covered	• Higher container utilisation • Use of more eco-friendly carriers
Air transportation	• kg moved • km covered	• Air to Sea-Air conversion
Port moves	• Number of containers	• Higher container utilisation • 20' to 40' conversion
Domestic distribution	• Transportation mode (truck vs. rail) • km covered • Volume moved	• Higher utilisation of delivery trucks/vans • Double-decker trailers • Increased use of rail • Use of bio-fuel
Warehousing	• Number of days in warehouse • Number of CBM	• Reduce safety stock • DC bypassing

Calculating the "Carbon Footprint" for ocean shipping

$$CO_2 \text{ Emissions} = \text{Distance} \times \text{No. of TEU} \times \text{Emission Factor}$$

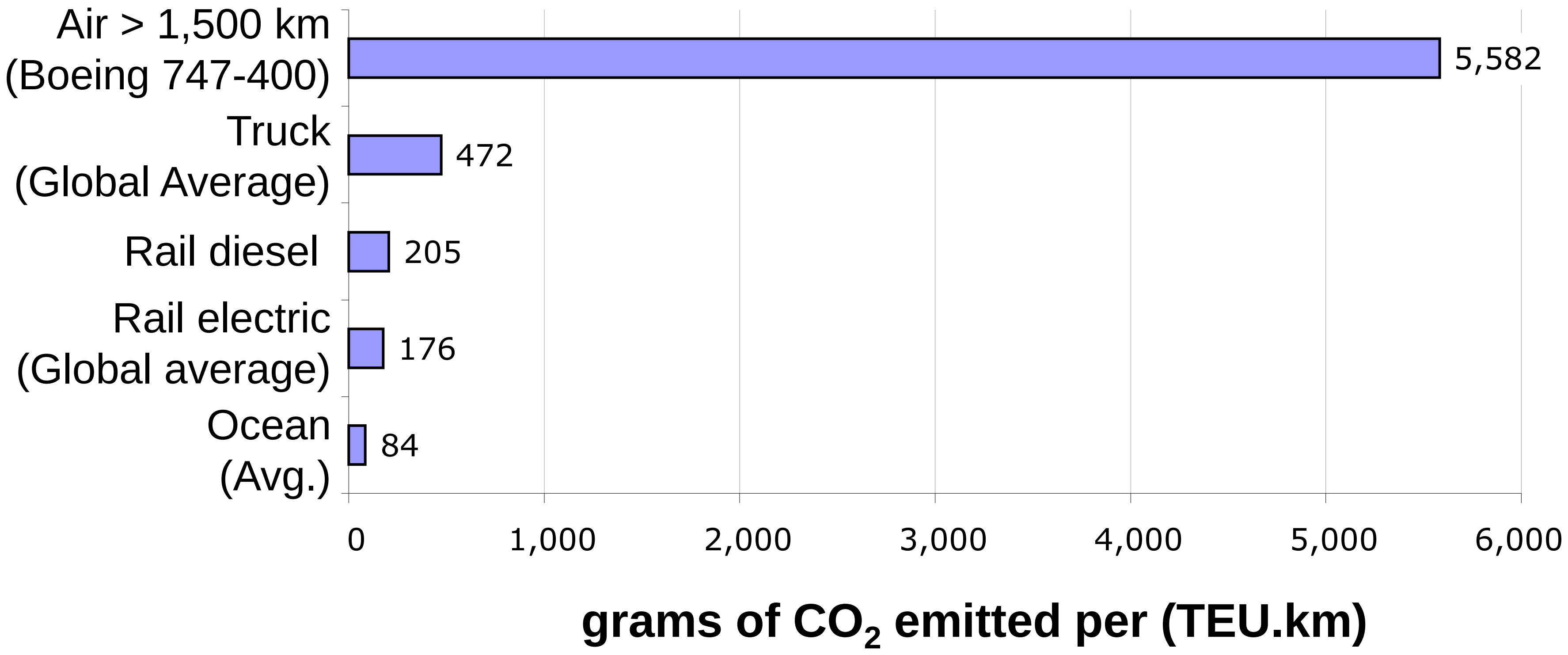
$$\text{g of } CO_2 = \text{km} \times \text{TEU} \times [\text{g of } CO_2 / (\text{TEU} \times \text{km})]$$

Emissions factor is weighted average of all ships on that particular route.

Basis: Greenhouse Gas Protocol '**Distance-based methodology**' for calculating CO_2 emissions.

CO_2 Emissions by Mode of Transportation

Ocean shipping has the lowest environmental impact for long distance transportation.



Green+Logistics or Green/Logistics?`

Green

- Environmental efficiency
- Recycling
- Compliance

Logistics

- Distributional efficiency
- Save time / money

Convergence?

4

Designing Distribution Networks and Applications to Online Sales

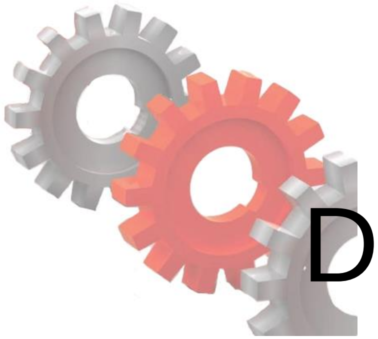
PowerPoint presentation to accompany Chopra and Meindl Supply Chain Management, 5e

The Role of Distribution in the Supply Chain

- *Distribution* – the steps taken to move and store a product from the supplier stage to the customer stage in a supply chain
- Drives profitability by directly affecting supply chain cost and the customer experience
- Choice of distribution network can achieve supply chain objectives from low cost to high responsiveness

Factors Influencing Distribution Network Design

- Distribution network performance evaluated along two dimensions
  1. Customer needs that are met
  2. Cost of meeting customer needs
- Evaluate the impact on customer service and cost for different distribution network options
- Profitability of the delivery network determined by revenue from met customer needs and network costs



Factors Influencing Distribution Network Design

- Elements of customer service influenced by network structure:
  - Response time
  - Product variety
  - Product availability
  - Customer experience
  - Order visibility
  - Returnability

Factors Influencing Distribution Network Design

- Supply chain costs affected by network structure:
  - Inventories
  - Transportation
  - Facilities and handling
  - Information

Design Options for a Distribution Network

- Distribution network choices from the manufacturer to the end consumer
- Two key decisions
    1. Will product be delivered to the customer location or picked up from a prearranged site?
    2. Will product flow through an intermediary (or intermediate location)?

Design Options for a Distribution Network

- One of six designs may be used
  1. Manufacturer storage with direct shipping
  2. Manufacturer storage with direct shipping and in-transit merge
  3. Distributor storage with carrier delivery
  4. Distributor storage with last-mile delivery
  5. Manufacturer/distributor storage with customer pickup
  6. Retail storage with customer pickup

Manufacturer Storage with Direct Shipping

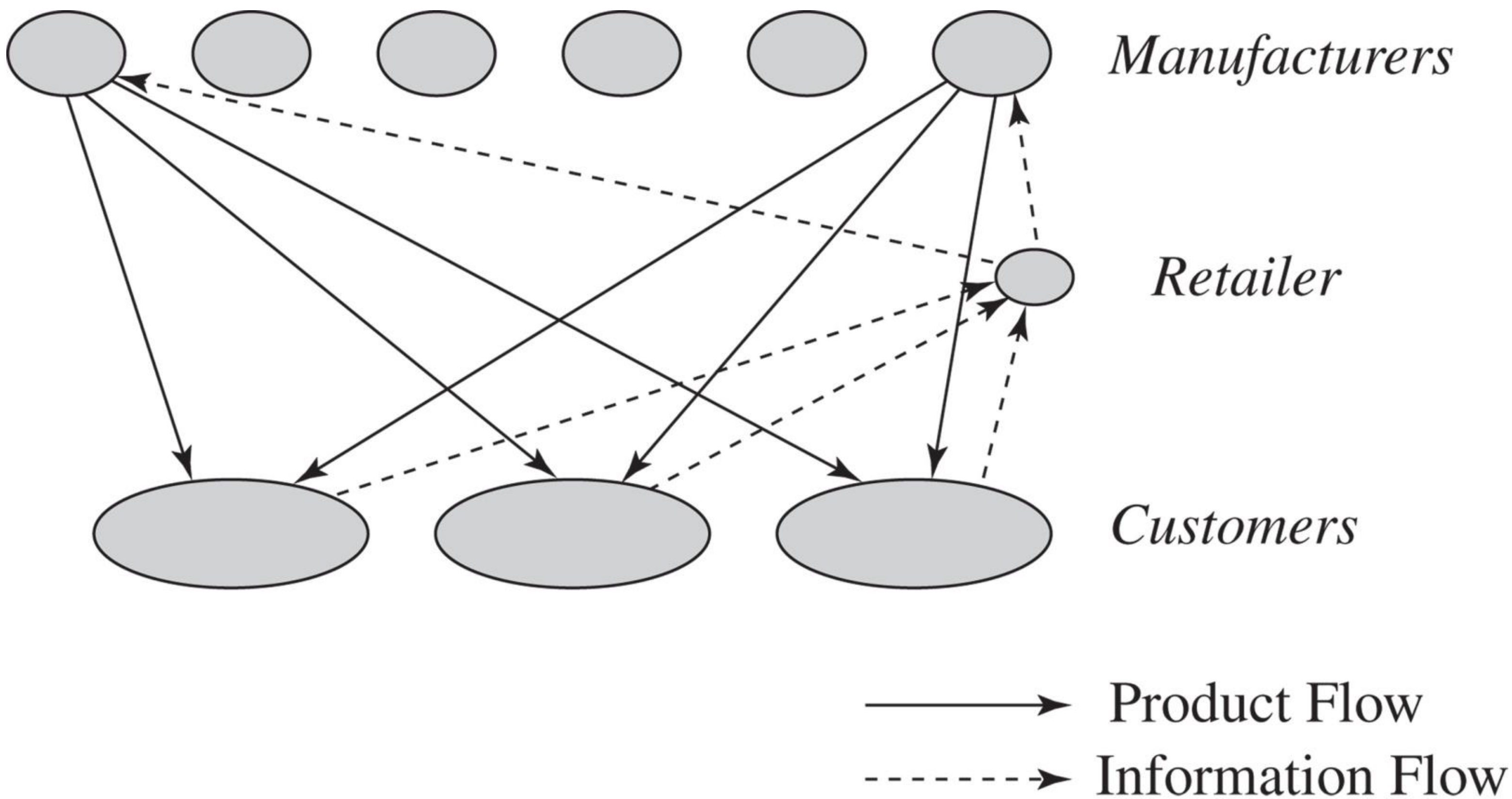


Figure 4-6

Manufacturer Storage with Direct Shipping Network

Cost Factor	Performance
Inventory	Lower costs because of aggregation. Benefits of aggregation are highest for low-demand, high-value items. Benefits are large if product customization can be postponed at the manufacturer.
Transportation	Higher transportation costs because of increased distance and disaggregate shipping.
Facilities and handling	Lower facility costs because of aggregation. Some saving on handling costs if manufacturer can manage small shipments or ship from production line.
Information	Significant investment in information infrastructure to integrate manufacturer and retailer.

Table 4-1

Manufacturer Storage with Direct Shipping Network

Service Factor	Performance
Response time	Long response time of one to two weeks because of increased distance and two stages for order processing. Response time may vary by product, thus complicating receiving.
Product variety	Easy to provide a high level of variety.
Product availability	Easy to provide a high level of product availability because of aggregation at manufacturer.
Customer experience	Good in terms of home delivery but can suffer if order from several manufacturers is sent as partial shipments.
Time to market	Fast, with the product available as soon as the first unit is produced.
Order visibility	More difficult but also more important from a customer service perspective.
Returnability	Expensive and difficult to implement.

Table 4-1

In-Transit Merge Network

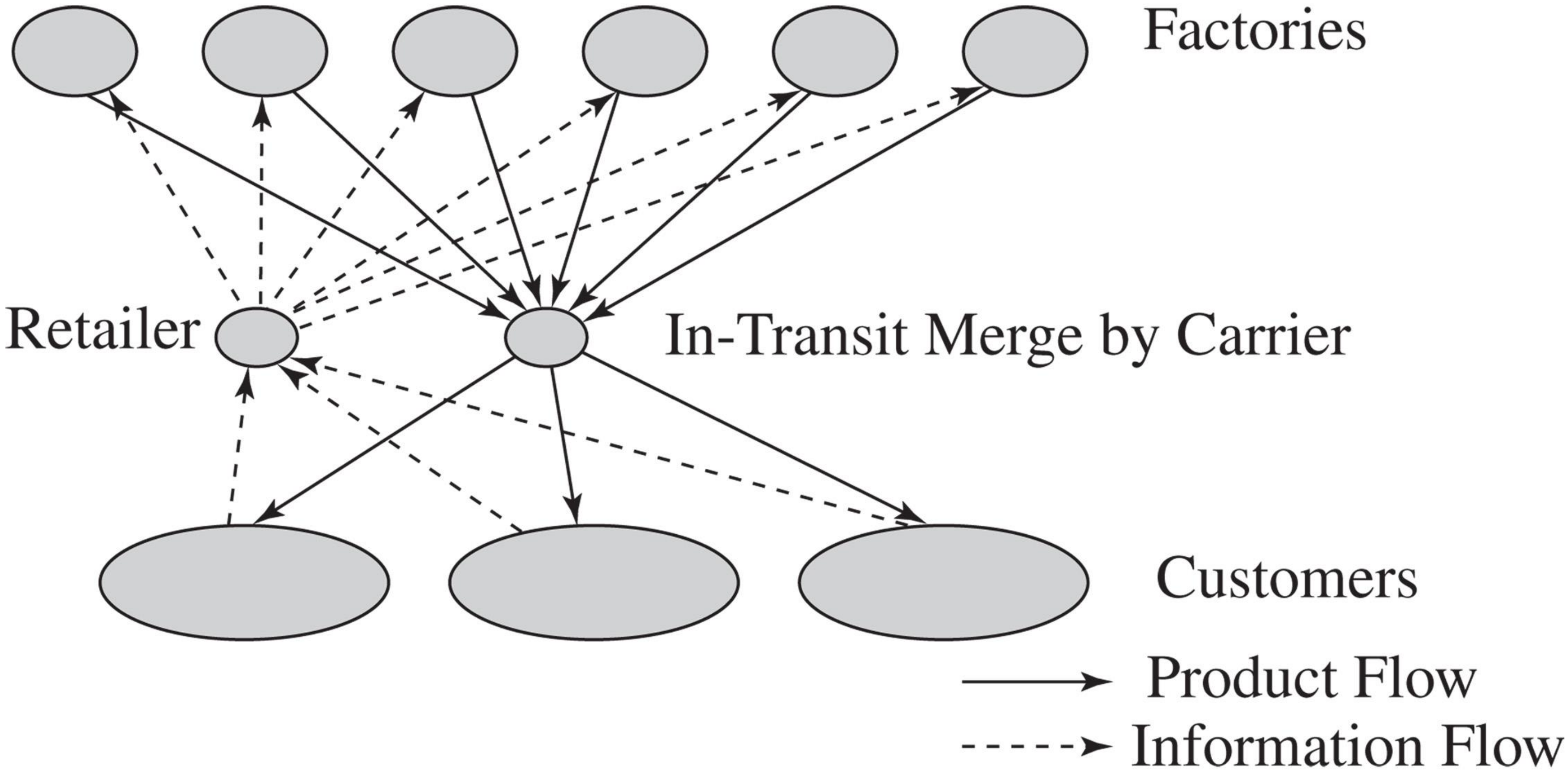


Figure 4-7

In-Transit Merge

Cost Factor	Performance
Inventory	Similar to drop-shipping.
Transportation	Somewhat lower transportation costs than drop-shipping.
Facilities and handling	Handling costs higher than drop-shipping at carrier; receiving costs lower at customer.
Information	Investment is somewhat higher than for drop-shipping.

Table 4-2

In-Transit Merge

Service Factor	Performance
Response time	Similar to drop-shipping; may be marginally higher.
Product variety	Similar to drop-shipping.
Product availability	Similar to drop-shipping.
Customer experience	Better than drop-shipping because only a single delivery has to be received.
Time to market	Similar to drop-shipping.
Order visibility	Similar to drop-shipping.
Returnability	Similar to drop-shipping.

Table 4-2

Distributor Storage with Carrier Delivery

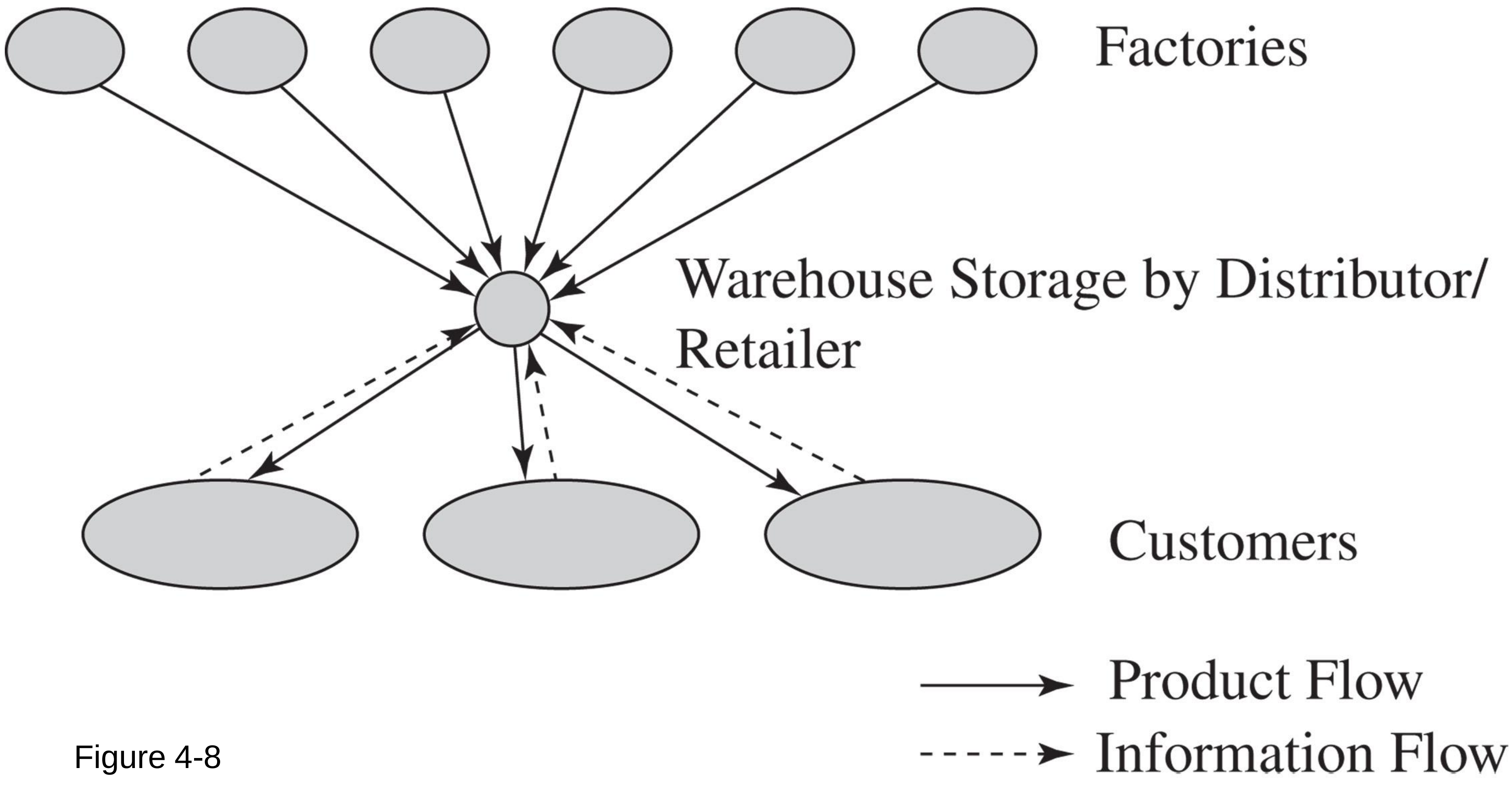


Figure 4-8

Distributor Storage with Carrier Delivery

Cost Factor	Performance
Inventory	Higher than manufacturer storage. Difference is not large for faster moving items but can be large for very slow-moving items.
Transportation	Lower than manufacturer storage. Reduction is highest for faster moving items.
Facilities and handling	Somewhat higher than manufacturer storage. The difference can be large for very slow-moving items.
Information	Simpler infrastructure compared to manufacturer storage.

Table 4-3

Distributor Storage with Carrier Delivery

Service Factor	Performance
Response time	Faster than manufacturer storage.
Product variety	Lower than manufacturer storage.
Product availability	Higher cost to provide the same level of availability as manufacturer storage.
Customer experience	Better than manufacturer storage with drop-shipping.
Time to market	Higher than manufacturer storage.
Order visibility	Easier than manufacturer storage.
Returnability	Easier than manufacturer storage.

Table 4-3

Distributor Storage with Last Mile Delivery

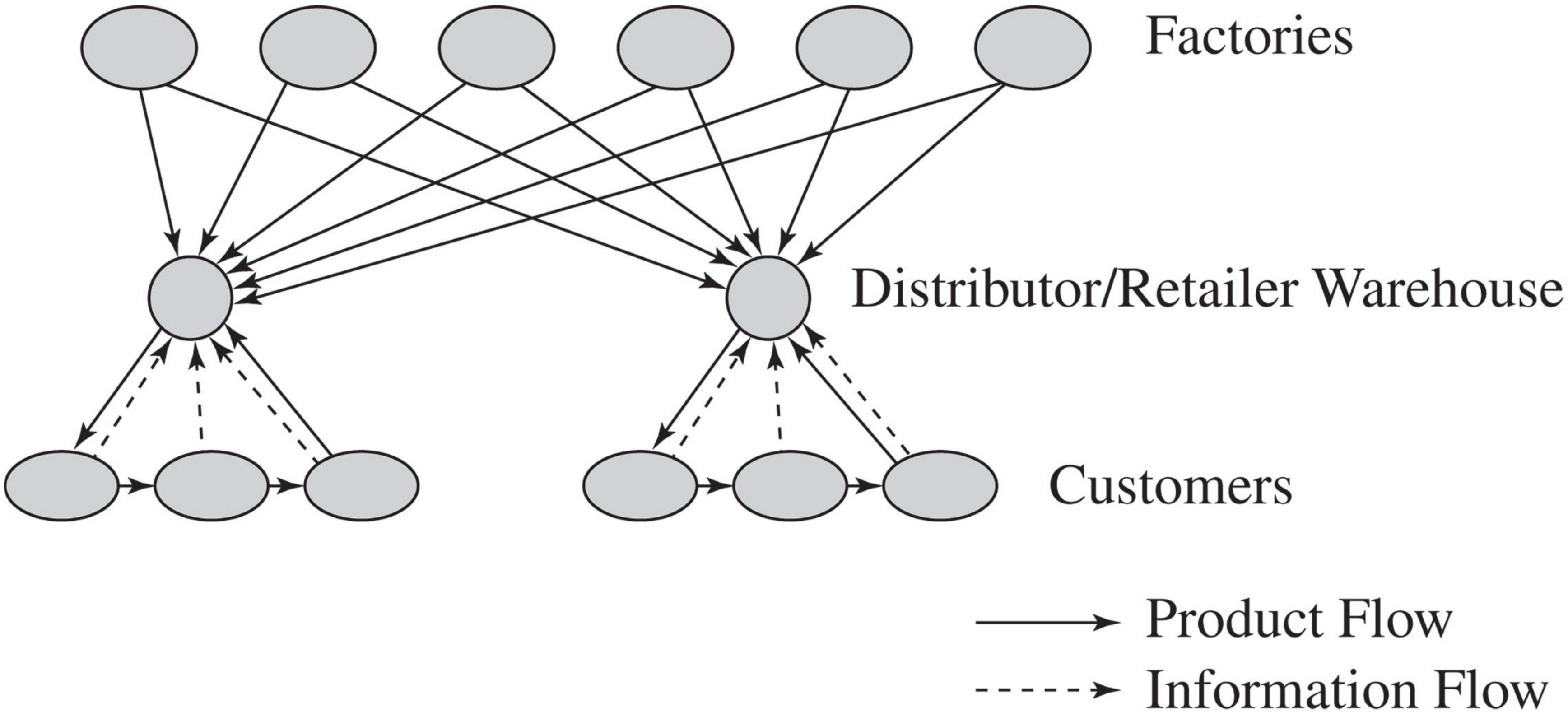


Figure 4-9

Distributor Storage with Last Mile Delivery

Cost Factor	Performance
Inventory	Higher than distributor storage with package carrier delivery.
Transportation	Very high cost given minimal scale economies. Higher than any other distribution option.
Facilities and handling	Facility costs higher than manufacturer storage or distributor storage with package carrier delivery, but lower than a chain of retail stores.
Information	Similar to distributor storage with package carrier delivery.

Table 4-4

Distributor Storage with Last Mile Delivery

Service Factor	Performance
Response time	Very quick. Same day to next-day delivery.
Product variety	Somewhat less than distributor storage with package carrier delivery but larger than retail stores.
Product availability	More expensive to provide availability than any other option except retail stores.
Customer experience	Very good, particularly for bulky items. Slightly higher than distributor storage with package carrier delivery.
Time to market	Less of an issue and easier to implement than manufacturer storage or distributor storage with package carrier delivery.
Order visibility	Easier to implement than other previous options.
Returnability	Harder and more expensive than a retail network.

Table 4-4

Manufacturer or Distributor Storage with Customer Pickup

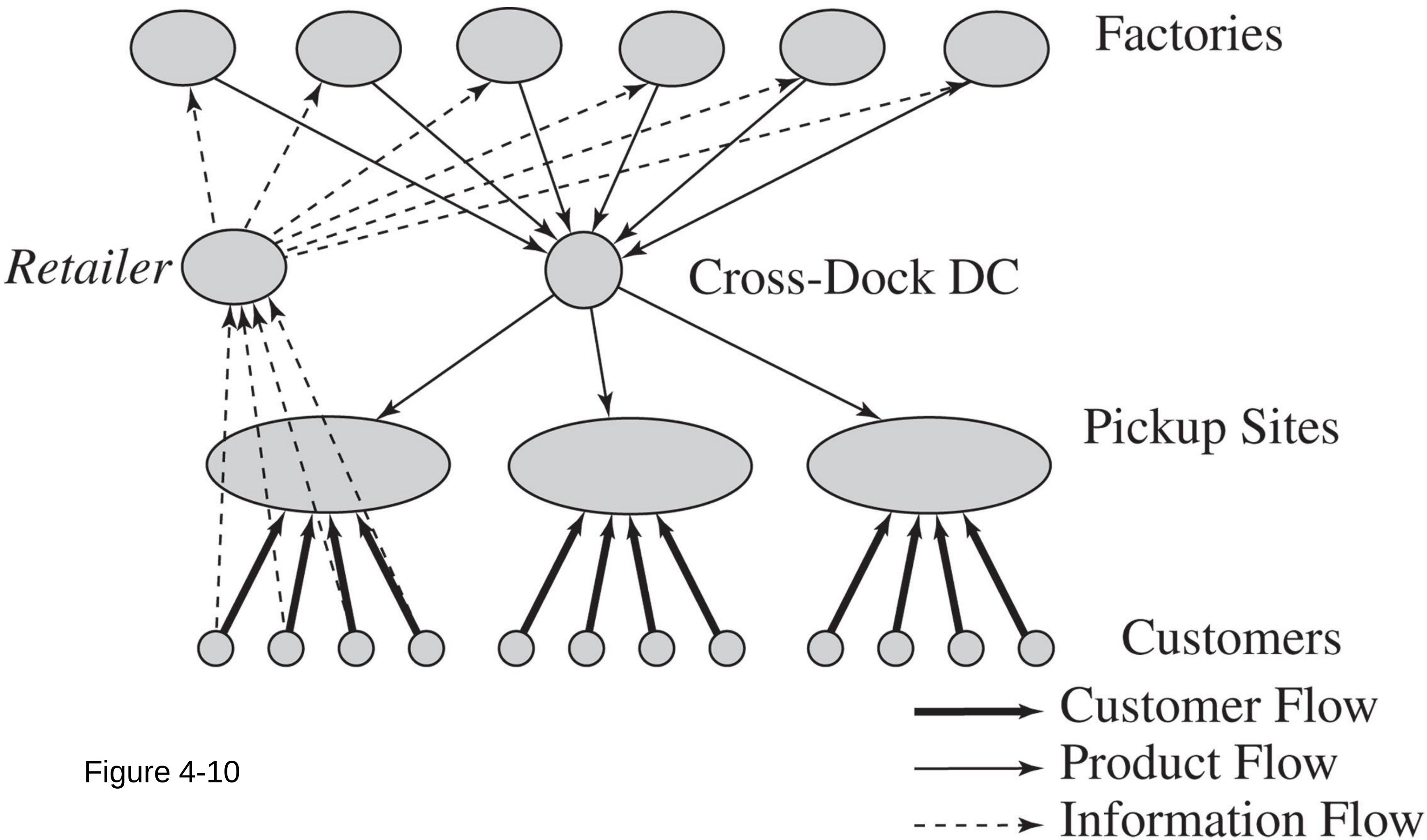


Figure 4-10

Manufacturer or Distributor Storage with Customer Pickup

Cost Factor	Performance
Inventory	Can match any other option, depending on the location of inventory.
Transportation	Lower than the use of package carriers, especially if using an existing delivery network.
Facilities and handling	Facility costs can be high if new facilities have to be built. Costs are lower if existing facilities are used. The increase in handling cost at the pickup site can be significant.
Information	Significant investment in infrastructure required.

Table 4-5

Manufacturer or Distributor Storage with Customer Pickup

Service Factor	Performance
Response time	Similar to package carrier delivery with manufacturer or distributor storage. Same-day delivery possible for items stored locally at pickup site.
Product variety	Similar to other manufacturer or distributor storage options.
Product availability	Similar to other manufacturer or distributor storage options.
Customer experience	Lower than other options because of the lack of home delivery. Experience is sensitive to capability of pickup location.
Time to market	Similar to manufacturer storage options.
Order visibility	Difficult but essential.
Returnability	Somewhat easier given that pickup location can handle returns.

Table 4-5

Retail Storage with Customer Pickup

Cost Factor	Performance
Inventory	Higher than all other options.
Transportation	Lower than all other options.
Facilities and handling	Higher than other options. The increase in handling cost at the pickup site can be significant for online and phone orders.
Information	Some investment in infrastructure required for online and phone orders.

Table 4-6

Retail Storage with Customer Pickup

Service Factor	Performance
Response time	Same-day (immediate) pickup possible for items stored locally at pickup site.
Product variety	Lower than all other options.
Product availability	More expensive to provide than all other options.
Customer experience	Related to whether shopping is viewed as a positive or negative experience by customer.
Time to market	Highest among distribution options.
Order visibility	Trivial for in-store orders. Difficult, but essential, for online and phone orders.
Returnability	Easier than other options because retail store can provide a substitute.

Table 4-6

Comparative Performance of Delivery Network Designs

	Retail Storage with Customer Pickup	Manufacturer Storage with Direct Shipping	Manufacturer Storage with In-Transit Merge	Distributor Storage with Package Carrier Delivery	Distributor Storage with Last-Mile Delivery	Manufacturer Storage with Pickup
Response time	1	4	4	3	2	4
Product variety	4	1	1	2	3	1
Product availability	4	1	1	2	3	1
Customer experience	Varies from 1 to 5	4	3	2	1	5
Time to market	4	1	1	2	3	1
Order visibility	1	5	4	3	2	6
Returnability	1	5	5	4	3	2
Inventory	4	1	1	2	3	1
Transportation	1	4	3	2	5	1
Facility and handling	6	1	2	3	4	5
Information	1	4	4	3	2	5

Key: 1 corresponds to the strongest performance and 6 the weakest performance.

Table 4-7

Delivery Networks for Different Product/ Customer Characteristics

	Retail Storage with Customer Pickup	Manufacturer Storage with Direct Shipping	Manufacturer Storage with In-Transit Merge	Distributor Storage with Package Carrier Delivery	Distributor Storage with Last-Mile Delivery	Manufacturer Storage with Pickup
High-demand product	+2	–2	–1	0	+1	–1
Medium-demand product	+1	–1	0	+1	0	0
Low-demand product	–1	+1	0	+1	–1	+1
Very low-demand product	–2	+2	+1	0	–2	+1
Many product sources	+1	–1	–1	+2	+1	0
High product value	–1	+2	+1	+1	0	+2
Quick desired response	+2	–2	–2	–1	+1	–2
High product variety	–1	+2	0	+1	0	+2
Low customer effort	–2	+1	+2	+2	+2	–1

Key: +2 = very suitable; +1 = somewhat suitable; 0 = neutral; –1 = somewhat unsuitable; –2 = very unsuitable.

Table 4-8

Distribution Networks in Practice

- Consider whether an exclusive distribution strategy is advantageous
- Product, price, commoditization, and criticality have an impact on the type of distribution system preferred by customers

5

Network Design in the Supply Chain

PowerPoint presentation to accompany Chopra and Meindl Supply Chain Management, 5e

Network Design Decisions

- Facility role
  - What role, what processes?
- Facility location
  - Where should facilities be located?
- Capacity allocation
  - How much capacity at each facility?
- Market and supply allocation
  - What markets? Which supply sources?

Factors Influencing Network Design Decisions

- Strategic factors
- Technological factors
- Macroeconomic factors
  - Tariffs and tax incentives
  - Exchange-rate and demand risk
  - Freight and fuel costs
- Political

Factors Influencing Network Design Decisions

- Infrastructure factors
- Competitive factors
  - Positive externalities between firms
  - Locating to split the market
- Customer response time and local presence
- Logistics and facility costs

Competitive Factors

– Positive externalities between firms

- Collocation benefits all

Figure 5-1

– Locating to split the market

- Locate to capture largest market share

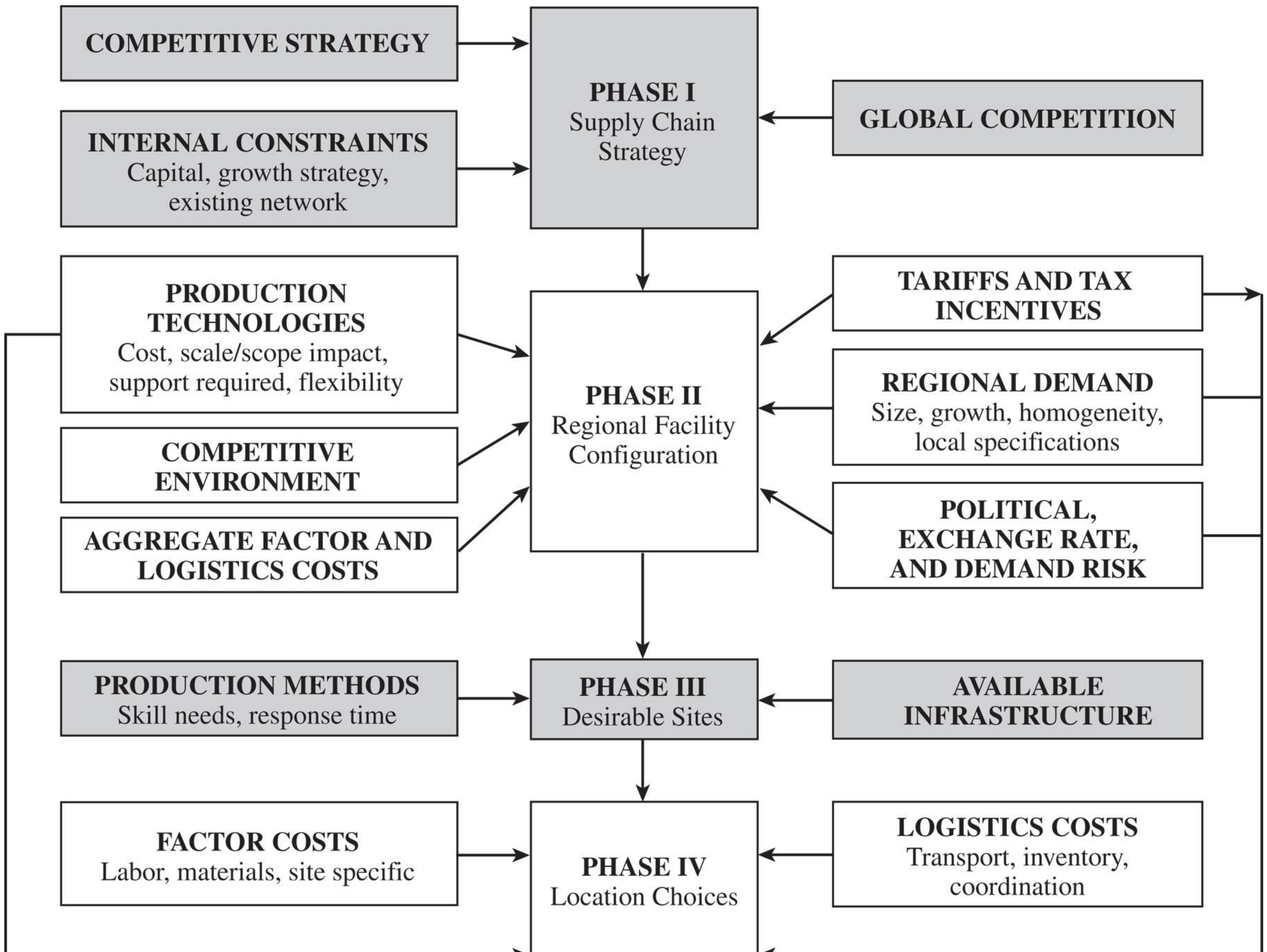
$$d_1 = a + \frac{1 - b - a}{2} \quad \text{and} \quad d_2 = \frac{1 + b - a}{2}$$

Framework for Network Design Decisions

- **Phase I: Define a Supply Chain Strategy/Design**
  - – Clear definition of the firm's competitive strategy
  - – Forecast the likely evolution of global competition
  - – Identify constraints on available capital
  - – Determine growth strategy

Framework for Network Design Decisions

Figure 5-2



Framework for Network Design Decisions

- **Phase II: Define the Regional Facility Configuration**
  – Forecast of the demand by country or region
  – Economies of scale or scope
  – Identify demand risk, exchange-rate risk, political risk, tariffs, requirements for local production, tax incentives, and export or import restrictions
  – Identify competitors

Framework for Network Design Decisions

- **Phase III: Select a Set of Desirable Potential Sites**
  - Hard infrastructure requirements
  - Soft infrastructure requirements
- **Phase IV: Location Choices**

Models for Facility Location and Capacity Allocation

- Maximize the overall profitability of the supply chain network while providing customers with the appropriate responsiveness
- Many trade-offs during network design
- Network design models used to decide on locations and capacities and to assign current demand to facilities

Models for Facility Location and Capacity Allocation

- Important information
  - Location of supply sources and markets
  - Location of potential facility sites
  - Demand forecast by market
  - Facility, labor, and material costs by site
  - Transportation costs between each pair of sites
  - Inventory costs by site and as a function of quantity
  - Sale price of product in different regions
  - Taxes and tariffs
  - Desired response time and other service factors

Phase II: Network Optimization Models

	A	B	C	D	E	F	G	H	I	J
1	***Inputs - Costs, Capacities, Demands***									
2		*Demand Region Production and Transportation Cost per 1,000,000 Units*					**Fixed**	**Low**	**Fixed**	**High**
3	*Supply Region*	N. America	S. America	Europe	Asia	Africa	**Cost ($)**	**Capacity**	**Cost ($)**	**Capacity**
4	N. America	81	92	101	130	115	6,000	10	9,000	20
5	S. America	117	77	108	98	100	4,500	10	6,750	20
6	Europe	102	105	95	119	111	6,500	10	9,750	20
7	Asia	115	125	90	59	74	4,100	10	6,150	20
8	Africa	142	100	103	105	71	4,000	10	6,000	20
9	*Demand*	12	8	14	16	7				

Figure 5-3

Capacitated Plant Location Model

n = number of potential plant locations/capacity

m = number of markets or demand points

D_j = annual demand from market j

K_i = potential capacity of plant i

f_i = annualized fixed cost of keeping plant i open

c_{ij} = cost of producing and shipping one unit from plant i to market j (cost includes production, inventory, transportation, and tariffs)

y_i = 1 if plant i is open, 0 otherwise

x_{ij} = quantity shipped from plant i to market j

$$Min \sum_{i=1}^{n} f_i y_i + \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij}$$

subject to

$$\sum_{i=1}^{n} x_{ij} = D_j \quad \text{for } j = 1,\ldots,m$$

$$\sum_{j=1}^{m} x_{ij} = K_i y_i \quad \text{for } i = 1,\ldots,n$$

$$y_i \in \{0,1\} \quad \text{for } i = 1,\ldots,n, x_{ij} \geq 0$$

Capacitated Plant Location Model

	A	B	C	D	E	F	G	H	I	J
1	***Inputs - Costs, Capacities, Demands***									
2		*Demand Region Production and Transportation Cost per 1,000,000 Units*					**Fixed**	**Low**	**Fixed**	**High**
3	*Supply Region*	N. America	S. America	Europe	Asia	Africa	**Cost ($)**	**Capacity**	**Cost ($)**	**Capacity**
4	N. America	81	92	101	130	115	6,000	10	9,000	20
5	S. America	117	77	108	98	100	4,500	10	6,750	20
6	Europe	102	105	95	119	111	6,500	10	9,750	20
7	Asia	115	125	90	59	74	4,100	10	6,150	20
8	Africa	142	100	103	105	71	4,000	10	6,000	20
9	*Demand*	12	8	14	16	7				
10										
11	***Decision Variables***									
12		*Demand Region - Production Allocation (Million Units)*					Plants	Plants		
13	*Supply Region*	N. America	S. America	Europe	Asia	Africa	(1=open)	(1=open)		
14	N. America	0	0	0	0	0	0	0		
15	S. America	0	0	0	0	0	0	0		
16	Europe	0	0	0	0	0	0	0		
17	Asia	0	0	0	0	0	0	0		
18	Africa	0	0	0	0	0	0	0		

Figure 5-4

Capacitated Plant Location Model

	A	B	C	D	E	F	G	H	I	J
1	***Inputs - Costs, Capacities, Demands***									
2		*Demand Region Production and Transportation Cost per 1,000,000 Units*					**Fixed**	**Low**	**Fixed**	**High**
3	*Supply Region*	N. America	S. America	Europe	Asia	Africa	**Cost ($)**	**Capacity**	**Cost ($)**	**Capacity**
4	N. America	81	92	101	130	115	6,000	10	9,000	20
5	S. America	117	77	108	98	100	4,500	10	6,750	20
6	Europe	102	105	95	119	111	6,500	10	9,750	20
7	Asia	115	125	90	59	74	4,100	10	6,150	20
8	Africa	142	100	103	105	71	4,000	10	6,000	20
9	*Demand*	12	8	14	16	7				
10										
11	***Decision Variables***									
12		*Demand Region - Production Allocation (Million Units)*					Plants	Plants		
13	*Supply Region*	N. America	S. America	Europe	Asia	Africa	(1=open)	(1=open)		
14	N. America	0	0	0	0	0	0	0		
15	S. America	0	0	0	0	0	0	0		
16	Europe	0	0	0	0	0	0	0		
17	Asia	0	0	0	0	0	0	0		
18	Africa	0	0	0	0	0	0	0		
19										
20	***Constraints***									
21	*Supply Region*	*Excess Capacity*								
22	N. America	0								
23	S. America	0								
24	Europe	0								
25	Asia	0								
26	Africa	0								
27		N. America	S. America	Europe	Asia	Africa				
28	*Unmet Demand*	12	8	14	16	7				
29										
30	***Objective Function***									
31	***Cost =***	$ -								

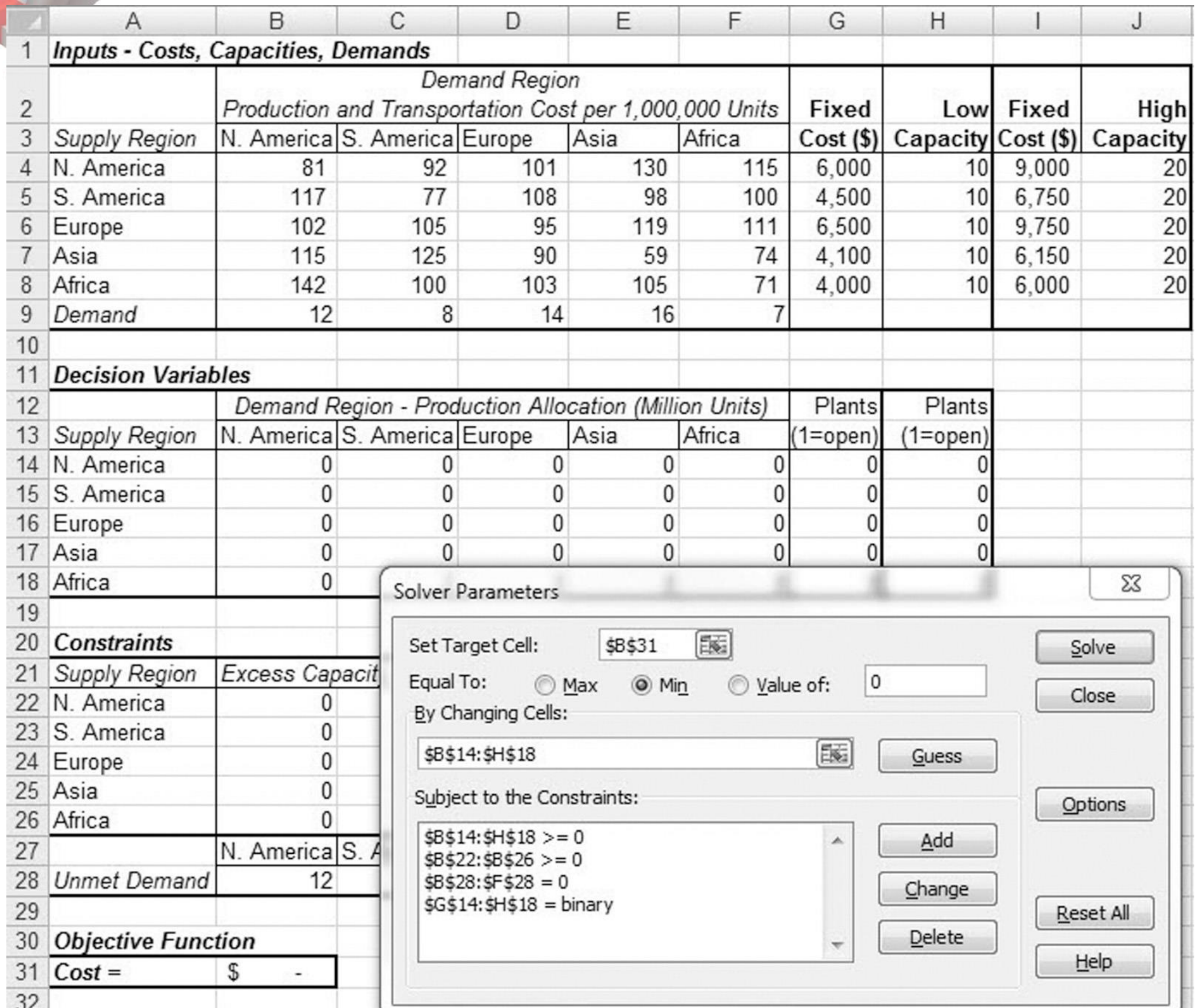
Figure 5-5

Capacitated Plant Location Model

Cell	Cell Formula	Equation	Copied to
B28	=B9 - SUM(B14:B18)	5.1	B28:F28
B22	=G14*H4 + H14*J4 - SUM(B14:F14)	5.2	B22:B26
B31	=SUMPRODUCT(B14:F18,B4:F8) + SUMPRODUCT(G14:G18,G4:G8) + SUMPRODUCT(H14:H18,I4:I8)	Objective Function	—

Figure 5-5

Phase III: Gravity Location Models



	A	B	C	D	E	F	G	H	I	J
1	***Inputs - Costs, Capacities, Demands***									
2		*Demand Region* *Production and Transportation Cost per 1,000,000 Units*					**Fixed**	**Low**	**Fixed**	**High**
3	*Supply Region*	N. America	S. America	Europe	Asia	Africa	**Cost ($)**	**Capacity**	**Cost ($)**	**Capacity**
4	N. America	81	92	101	130	115	6,000	10	9,000	20
5	S. America	117	77	108	98	100	4,500	10	6,750	20
6	Europe	102	105	95	119	111	6,500	10	9,750	20
7	Asia	115	125	90	59	74	4,100	10	6,150	20
8	Africa	142	100	103	105	71	4,000	10	6,000	20
9	*Demand*	12	8	14	16	7				
10										
11	***Decision Variables***									
12		*Demand Region - Production Allocation (Million Units)*					Plants	Plants		
13	*Supply Region*	N. America	S. America	Europe	Asia	Africa	(1=open)	(1=open)		
14	N. America	0	0	0	0	0	0	0		
15	S. America	0	0	0	0	0	0	0		
16	Europe	0	0	0	0	0	0	0		
17	Asia	0	0	0	0	0	0	0		
18	Africa	0								
19										
20	***Constraints***									
21	*Supply Region*	*Excess Capacit*								
22	N. America	0								
23	S. America	0								
24	Europe	0								
25	Asia	0								
26	Africa	0								
27		N. America	S. A							
28	*Unmet Demand*	12								
29										
30	***Objective Function***									
31	***Cost =***	$ -								
32										

Figure 5-6

Gravity Location Model

x_n, y_n: coordinate location of either a market or supply source n
F_n: cost of shipping one unit for one mile between the facility and either market or supply source n
D_n: quantity to be shipped between facility and market or supply source n

(x, y) is the location selected for the facility, the distance d_n between the facility at location (x, y) and the supply source or market n is given by

$$d_n = \sqrt{(x - x_n)^2 + (y - y_n)^2}$$

Gravity Location Model

	A	B	C	D	E	F	G	H	I	J
1	***Inputs - Costs, Capacities, Demands***									
2		*Demand Region Production and Transportation Cost per 1,000,000 Units*					**Fixed**	**Low**	**Fixed**	**High**
3	*Supply Region*	N. America	S. America	Europe	Asia	Africa	**Cost ($)**	**Capacity**	**Cost ($)**	**Capacity**
4	N. America	81	92	101	130	115	6,000	10	9,000	20
5	S. America	117	77	108	98	100	4,500	10	6,750	20
6	Europe	102	105	95	119	111	6,500	10	9,750	20
7	Asia	115	125	90	59	74	4,100	10	6,150	20
8	Africa	142	100	103	105	71	4,000	10	6,000	20
9	*Demand*	12	8	14	16	7				
10										
11	***Decision Variables***									
12		*Demand Region - Production Allocation (Million Units)*					Plants	Plants		
13	*Supply Region*	N. America	S. America	Europe	Asia	Africa	(1=open)	(1=open)		
14	N. America	0	0	0	0	0	0	0		
15	S. America	12	8	0	0	0	0	1		
16	Europe	0	0	0	0	0	0	0		
17	Asia	0	0	4	16	0	0	1		
18	Africa	0	0	10	0	7	0	1		
19										
20	***Constraints***									
21	*Supply Region*	*Excess Capacity*								
22	N. America	0								
23	S. America	0								
24	Europe	0								
25	Asia	0								
26	Africa	3								
27		N. America	S. America	Europe	Asia	Africa				
28	*Unmet Demand*	0	0	0	0	0				
29										
30	***Objective Function***									
31	***Cost =***	$ 23,751								

Figure 5-7

Gravity Location Model

Sources/Markets	Transportation Cost \$/Ton Mile (F_n)	Quantity in Tons (D_n)	Coordinates x_n	y_n
Supply sources				
Buffalo	0.90	500	700	1,200
Memphis	0.95	300	250	600
St. Louis	0.85	700	225	825
Markets				
Atlanta	1.50	225	600	500
Boston	1.50	150	1,050	1,200
Jacksonville	1.50	250	800	300
Philadelphia	1.50	175	925	975
New York	1.50	300	1,000	1,080

Table 5-1

Total transportation cost $TC = \sum_{n=1}^{k} d_n D_n F_n$

Gravity Location Model

Sources/ Markets		$/Ton Mile F_n	Tons D_n	Coordinates x_n	Coordinates y_n	d_n
Sources	Buffalo	0.90	500	700	1200	1389
	Memphis	0.95	300	250	600	650
	St. Louis	0.85	700	225	825	855
Markets	Atlanta	1.50	225	600	500	781
	Boston	1.50	150	1050	1200	1595
	Jacksonville	1.50	250	800	300	854
	Philadelphia	1.50	175	925	975	1344
	New York	1.50	300	1000	1080	1472

Facility Location

x =	0.0
y =	0.0
Cost =	$3,277,110

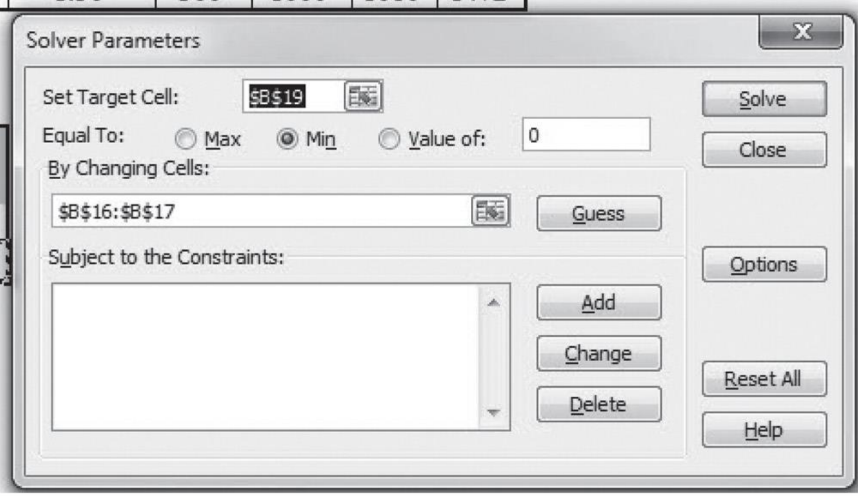


Figure 5-8

Gravity Location Model

Cell	Cell Formula	Equation	Copied to
G5	=SQRT((B16-E5)^2+(B17-F5)^2)	5.1	G5:G12
B19	=SUMPRODUCT(G5:G12,D5:D12,C5:C12)	5.2	—

Figure 5-8

Gravity Location Model

1. For each supply source or market n, evaluate d_n
2. Obtain a new location (x', y') for the facility, where

$$x' = \frac{\sum_{n=1}^{k} \frac{D_n F_n x_n}{d_n}}{\sum_{n=1}^{k} \frac{D_n F_n}{d_n}} \quad \text{and} \quad y' = \frac{\sum_{n=1}^{k} \frac{D_n F_n y_n}{d_n}}{\sum_{n=1}^{k} \frac{D_n F_n}{d_n}}$$

3. If the new location (x', y') is almost the same as (x, y) stop. Otherwise, set $(x, y) = (x', y')$ and go to step 1

Phase IV: Network Optimization Models

Supply City	Demand City Production and Transportation Cost per Thousand Units (Thousand $) Atlanta	Boston	Chicago	Denver	Omaha	Portland	Monthly Capacity (Thousand Units) K	Monthly Fixed Cost (Thousand $) f
Baltimore	1,675	400	985	1,630	1,160	2,800	18	7,650
Cheyenne	1,460	1,940	970	100	495	1,200	24	3,500
Salt Lake City	1,925	2,400	1,450	500	950	800	27	5,000
Memphis	380	1,355	543	1,045	665	2,321	22	4,100
Wichita	922	1,646	700	508	311	1,797	31	2,200
Monthly demand (thousand units) D_j	10	8	14	6	7	11		

Table 5-2

Network Optimization Models

- Allocating demand to production facilities

n = number of factory locations

m = number of markets or demand points

D_j = annual demand from market j

K_i = capacity of factory i

c_{ij} = cost of producing and shipping one unit from factory i to market j

x_{ij} = quantity shipped from factory i to market j

$$Min \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij}$$

subject to

$$\sum_{i=1}^{n} x_{ij} = D_j \quad \text{for } j = 1, \ldots, m$$

$$\sum_{j=1}^{m} x_{ij} = K_i \quad \text{for } i = 1, \ldots, n$$

Network Optimization Models

- Optimal demand allocation

		Atlanta	Boston	Chicago	Denver	Omaha	Portland
TelecomOne	Baltimore	0	8	2			
	Memphis	10	0	12			
	Wichita	0	0	0			
HighOptic	Salt Lake				0	0	11
	Cheyenne				6	7	0

Table 5-3

Capacitated Plant Location Model

- Merge the companies
- Solve using location-specific costs

y_i = 1 if factory i is open, 0 otherwise
x_{ij} = quantity shipped from factory i to market j

$$Min \sum_{i=1}^{n} f_i y_i + \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij}$$

Capacitated Plant Location Model

Inputs - Costs, Capacities, Demands (for TelecomOptic)

	Demand City — Production and Transportation Cost per 1000 Units							
Supply City	Atlanta	Boston	Chicago	Denver	Omaha	Portland	**Fixed Cost ($)**	**Capacity**
Baltimore	1,675	400	685	1,630	1,160	2,800	7,650	18
Cheyenne	1,460	1,940	970	100	495	1,200	3,500	24
Salt Lake	1,925	2,400	1,425	500	950	800	5,000	27
Memphis	380	1,355	543	1,045	665	2,321	4,100	22
Wichita	922	1,646	700	508	311	1,797	2,200	31
Demand	10	8	14	6	7	11		

Decision Variables

	Demand City - Production Allocation (1000 Units)						**Plants**
Supply City	Atlanta	Boston	Chicago	Denver	Omaha	Portland	(1=open)
Baltimore	0	0	0	0	0	0	0
Cheyenne	0	0	0	0	0	0	0
Salt Lake	0	0	0	0	0	0	0
Memphis	0	0	0	0	0	0	0
Wichita	0	0	0	0	0	0	0

Figure 5-9

Capacitated Plant Location Model

	A	B	C	D	E	F	G	H	I
1	***Inputs - Costs, Capacities, Demands (for TelecomOptic)***								
2		*Demand City Production and Transportation Cost per 1000 Units*						**Fixed**	
3	*Supply City*	Atlanta	Boston	Chicago	Denver	Omaha	Portland	**Cost ($)**	**Capacity**
4	Baltimore	1,675	400	685	1,630	1,160	2,800	7,650	18
5	Cheyenne	1,460	1,940	970	100	495	1,200	3,500	24
6	Salt Lake	1,925	2,400	1,425	500	950	800	5,000	27
7	Memphis	380	1,355	543	1,045	665	2,321	4,100	22
8	Wichita	922	1,646	700	508	311	1,797	2,200	31
9	*Demand*	10	8	14	6	7	11		
11	***Decision Variables***								
12		*Demand City - Production Allocation (1000 Units)*						**Plants**	
13	*Supply City*	Atlanta	Boston	Chicago	Denver	Omaha	Portland	(1=open)	
14	Baltimore	0	0	0	0	0	0	0	
15	Cheyenne	0	0	0	0	0	0	0	
16	Salt Lake	0	0	0	0	0	0	0	
17	Memphis	0	0	0	0	0	0	0	
18	Wichita	0	0	0	0	0	0	0	
20	***Constraints***								
21	*Supply City*	*Excess Capacity*							
22	Baltimore	0							
23	Cheyenne	0							
24	Salt Lake	0							
25	Memphis	0							
26	Wichita	0							
28		Atlanta	Boston	Chicago	Denver	Omaha	Portland		
29	*Unmet Demand*	10	8	14	6	7	11		
31	***Objective Function***								
32	***Cost =***	$ -							

Figure 5-10

Capacitated Plant Location Model

Cell	Formula	Equation	Copied to
B22	= I4*H14 - SUM(B14:G14)	5.7	B23:B26
B29	= B9 - SUM(B14:B18)	5.6	C29:G29
B32	= SUMPRODUCT(B4:G8, B14:G18) + SUMPRODUCT(H4:H8, H14:H18)	Objective function	—

Figure 5-10

Capacitated Plant Location Model

Inputs - Costs, Capacities, Demands (for TelecomOptic)

	Demand City Production and Transportation Cost per 1000 Units							
Supply City	Atlanta	Boston	Chicago	Denver	Omaha	Portland	Fixed Cost ($)	Capacity
Baltimore	1,675	400	685	1,630	1,160	2,800	7,650	18
Cheyenne	1,460	1,940	970	100	495	1,200	3,500	24
Salt Lake	1,925	2,400	1,425	500	950	800	5,000	27
Memphis	380	1,355	543	1,045	665	2,321	4,100	22
Wichita	922	1,646	700	508	311	1,797	2,200	31
Demand	10	8	14	6	7	11		

Decision Variables

	Demand City - Production Allocation (1000 Units)						Plants
Supply City	Atlanta	Boston	Chicago	Denver	Omaha	Portland	(1=open)
Baltimore	0	0	0	0	0	0	0
Cheyenne	0	0	0	0	0	0	0
Salt Lake	0	0	0	0	0	0	0
Memphis	0	0	0	0	0	0	0
Wichita	0	0	0	0	0	0	0

Constraints

Supply City	*Excess Capacity*
Baltimore	0
Cheyenne	0
Salt Lake	0
Memphis	0
Wichita	0

	Atlanta	Boston	Chicago	Denver	Omaha	Portland
Unmet Demand	10	8	14	6	7	11

Objective Function

Cost =	$ -

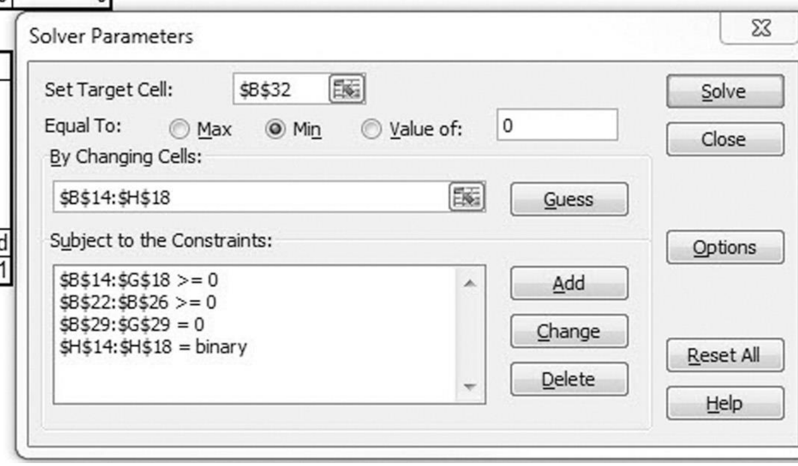


Figure 5-11

Capacitated Model With Single Sourcing

- Market supplied by only one factory
- Modify decision variables

y_i = 1 if factory i is open, 0 otherwise
x_{ij} = 1 if market j is supplied by factory i, 0 otherwise

$$Min \sum_{i=1}^{n} f_i y_i + \sum_{i=1}^{n} \sum_{j=1}^{m} D_j c_{ij} x_{ij}$$

subject to

$$\sum_{i=1}^{n} x_{ij} = 1 \text{ for } j = 1,\ldots,m$$

$$\sum_{j=1}^{m} D_i x_{ij} \le K_i y_i \text{ for } i = 1,\ldots,n$$

$$x_{ij}, y_i \in \{0,1\}$$

Capacitated Model With Single Sourcing

Inputs - Costs, Capacities, Demands (for TelecomOptic)

Supply City	Atlanta	Boston	Chicago	Denver	Omaha	Portland	Fixed Cost ($)	Capacity
	Demand City Production and Transportation Cost per 1000 Units							
Baltimore	1,675	400	685	1,630	1,160	2,800	7,650	18
Cheyenne	1,460	1,940	970	100	495	1,200	3,500	24
Salt Lake	1,925	2,400	1,425	500	950	800	5,000	27
Memphis	380	1,355	543	1,045	665	2,321	4,100	22
Wichita	922	1,646	700	508	311	1,797	2,200	31
Demand	10	8	14	6	7	11		

Decision Variables

Supply City	Atlanta	Boston	Chicago	Denver	Omaha	Portland	Plants (1=open)
	Demand City - Production Allocation (1000 Units)						
Baltimore	0	8	2	0	0	0	1
Cheyenne	0	0	0	6	7	11	1
Salt Lake	0	0	0	0	0	0	0
Memphis	10	0	12	0	0	0	1
Wichita	0	0	0	0	0	0	0

Constraints

Supply City	Excess Capacity
Baltimore	8
Cheyenne	0
Salt Lake	0
Memphis	0
Wichita	0

	Atlanta	Boston	Chicago	Denver	Omaha	Portland
Unmet Demand	0	0	0	0	0	0

Objective Function

Cost = $ 47,401

Figure 5-12

Capacitated Model With Single Sourcing

- Optimal network configuration with single sourcing

	Open/ Closed	Atlanta	Boston	Chicago	Denver	Omaha	Portland
Baltimore	Closed	0	0	0	0	0	0
Cheyenne	Closed	0	0	0	0	0	0
Salt Lake	Open	0	0	0	6	0	11
Memphis	Open	10	8	0	0	0	0
Wichita	Open	0	0	14	0	7	0

Table 5-4

Locating Plants and Warehouses Simultaneously

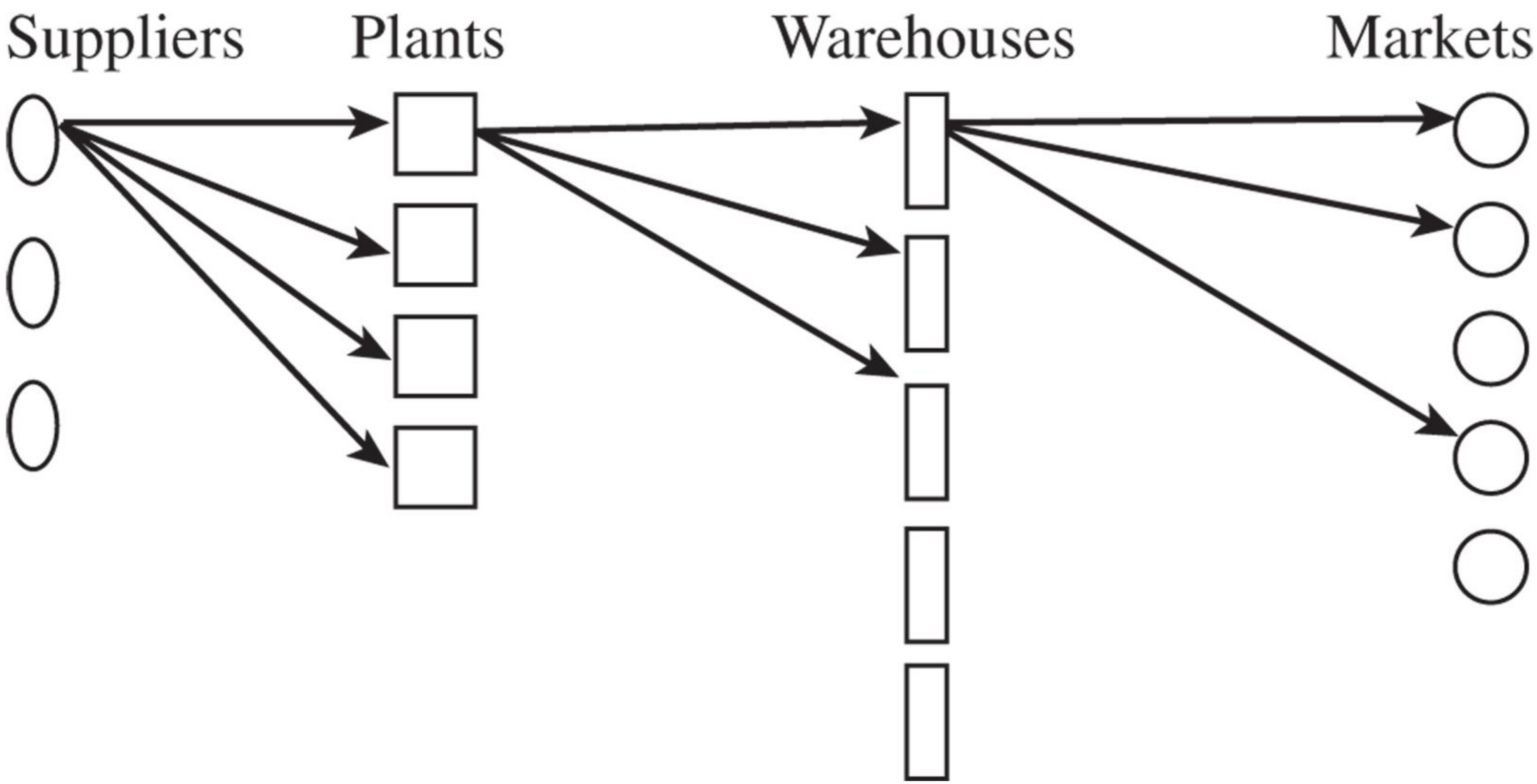


Figure 5-13

Locating Plants and Warehouses Simultaneously

- Model inputs

m = number of markets or demand points
n = number of potential factory locations
l = number of suppliers
t = number of potential warehouse locations
D_j = annual demand from customer j
K_i = potential capacity of factory at site i
S_h = supply capacity at supplier h
W_e = potential warehouse capacity at site e
F_i = fixed cost of locating a plant at site i
f_e = fixed cost of locating a warehouse at site e
c_{hi} = cost of shipping one unit from supply source h to factory i
c_{ie} = cost of producing and shipping one unit from factory i to warehouse e
c_{ej} = cost of shipping one unit from warehouse e to customer j

Locating Plants and Warehouses Simultaneously

- Goal is to identify plant and warehouse locations and quantities shipped that minimize the total fixed and variable costs

Y_i = 1 if factory is located at site i, 0 otherwise
Y_e = 1 if warehouse is located at site e, 0 otherwise
x_{ej} = quantity shipped from warehouse e to market j
x_{ie} = quantity shipped from factory at site i to warehouse e
x_{hi} = quantity shipped from supplier h to factory at site i

$$Min \sum_{i=1}^{n} F_i y_i + \sum_{e=1}^{t} f_e y_e + \sum_{h=1}^{l} \sum_{i=1}^{n} c_{hi} x_{ie} + \sum_{e=1}^{t} \sum_{j=1}^{m} c_{ej} x_{ej}$$

Locating Plants and Warehouses Simultaneously

subject to

$$\sum_{i=1}^{n} x_{hi} \le S_h \quad \text{for } h = 1,\dots,l$$

$$\sum_{h=1}^{l} x_{hi} - \sum_{e=1}^{t} x_{ie} \ge 0 \quad \text{for } i = 1,\dots,n$$

$$\sum_{e=1}^{t} x_{ie} \le K_i y_i \quad \text{for } i = 1,\dots,n$$

$$\sum_{i=1}^{n} x_{ie} - \sum_{j=1}^{m} x_{ej} \ge 0 \quad \text{for } e = 1,\dots,t$$

$$\sum_{j=1}^{m} x_{ej} \le W_e y_e \quad \text{for } e = 1,\dots,t$$

$$\sum_{e=1}^{t} x_{ej} = D_j \quad \text{for } j = 1,\dots,m$$

$$y_i, y_e \in \{0,1\}, x_{ej}, x_{ie}, x_{hi} \ge 0$$

Accounting for Taxes, Tariffs, and Customer Requirements

- A supply chain network should maximize profits after tariffs and taxes while meeting customer service requirements
- Modified objective and constraint

$$Max \sum_{j=1}^{m} r_j \sum_{i=1}^{n} x_{ij} - \sum_{i=1}^{n} F_i y_i - \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij}$$

$$\sum_{i=1}^{n} x_{ij} \le D_j \quad \text{for } j = 1, \ldots, m$$

6

Designing Global Supply Chain Networks

PowerPoint presentation to accompany
Chopra and Meindl Supply Chain Management, 5e

Impact of Globalization on Supply Chain Networks

Risk Factors	Percentage of Supply Chains Impacted
Natural disasters	35
Shortage of skilled resources	24
Geopolitical uncertainty	20
Terrorist infiltration of cargo	13
Volatility of fuel prices	37
Currency fluctuation	29
Port operations/custom delays	23
Customer/consumer preference shifts	23
Performance of supply chain partners	38
Logistics capacity/complexity	33
Forecasting/planning accuracy	30
Supplier planning/communication issues	27
Inflexible supply chain technology	21

Table 6-1

Chapter 5

DEMAND FORECASTING

Forecasting Techniques

- **Qualitative forecasting** is based on opinion & intuition.
- **Quantitative forecasting** uses mathematical models & historical data to make forecasts.
- **Time series** models are the most frequently used among all the forecasting models.

Forecasting Techniques *(Continued)*

Qualitative Forecasting Methods

Generally used when data are limited, unavailable, or not currently relevant. Forecast depends on skill & experience of forecaster(s) & available information

Four qualitative models used are –

1. **Jury of executive opinion**
2. **Delphi method**
3. **Sales force composite**
4. **Consumer survey**

Forecasting Techniques (*Continued*)

Quantitative Methods

- **Time series forecasting** – based on the assumption that the future is an extension of the past. Historical data is used to predict future demand

- **Cause & Effect forecasting** – assumes that one or more factors (independent variables) predict future demand

It is generally recommended to use a combination of quantitative & qualitative techniques

Forecasting Techniques (*Continued*)

Components of Time Series

Data should be plotted to detect for the following components –

- Trend variations: increasing or decreasing over many years
- Cyclical variations: wavelike movements that are longer than a year (e.g., business cycle)
- Seasonal variations: show peaks & valleys that repeat over a consistent interval such as hours, days, weeks, months, seasons, or years
- Random variations: due to unexpected or unpredictable events

Forecasting Techniques (*Continued*)

Time Series Forecasting Models

Naïve Forecast – the estimate of the next period is equal to the demand in the past period.

$$F_{t+1} = A_t$$

Where F_{t+1} = forecast for period $t+1$

A_t = actual demand for period t

Forecasting Techniques (*Continued*)

Time Series Forecasting Models

Simple Moving Average Forecast – uses historical data to generate a forecast. Works well when demand is stable over time.

$$F_{t+1} = \frac{\sum_{i=t-n+1}^{t} A_i}{n}$$

Where F_{t+1} = forecast for period $t+1$

A_t = actual demand for period t

n = number of periods to calculate moving average

Forecasting Techniques *(Continued)*

Time Series Forecasting Models

Weighted Moving Average Forecast – is based on an n-period weighted moving average

$$F_{t=1} = \sum_{i=t-n+1}^{t} w_i A_i$$

where

F_{t+1} = forecast for Period $t + 1$,

n = number of periods used in determining the moving average,

A_i = actual demand in Period i, and

w_i = weight assigned to Period i (with $\Sigma w_i = 1$).

Time Series Forecasting Models

Exponential Smoothing Forecast – a type of weighted moving average where only two data points are needed

$$F_{t+1} = F_t + \alpha(A_t - F_t) \text{ or } F_{t+1} = \alpha A_t + (1 - \alpha)\, F_t$$

Where F_{t+1} = forecast for Period $t + 1$

F_t = forecast for Period t

A_t = actual demand for Period t

α = smoothing constant ($0 \le \alpha \le 1$)

Time Series Forecasting Models

Linear Trend Forecast – trend can be estimated using simple linear regression to fit a line to a time series

$$\hat{Y} = b_0 + b_1 x$$

Where $\hat{Y}$ = forecast or dependent variable

x = time variable

b_0 = intercept of the line

b_1 = slope of the line

Forecast Accuracy *(Continued)*

Several measures of forecasting accuracy follow –

- **Mean absolute deviation (MAD)-** a MAD of 0 indicates the forecast exactly predicted demand
- **Mean absolute percentage error (MAPE)-** provides a perspective of the true magnitude of the forecast error
- **Mean squared error (MSE)-** analogous to variance, large forecast errors are heavily penalized

Forecast Accuracy *(Continued)*

Mean absolute deviation (MAD)-

MAD of 0 indicates the forecast exactly predicted demand.

$$\text{Mean absolute deviation (MAD)} = \frac{\sum_{i=1}^{n} |e_t|}{n}$$

Where e_t = forecast error for period t

A_t = actual demand for period *t*

n = number of periods of evaluation

Forecast Accuracy (*Continued*)

Mean absolute percentage error (MAPE) –

provides a perspective of the true magnitude of the forecast error.

$$\text{Mean absolute percentage error (MAPE)} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{e_t}{A_t}\right|(100)$$

Where e_t = forecast error for period t

A_t = actual demand for period *t*

n = number of periods of evaluation

Forecast Accuracy *(Continued)*

Mean squared error (MSE) –

analogous to variance, large forecast errors are heavily penalized

$$\text{Mean squared error (MSE)} = \frac{\sum_{t=1}^{n} e_t^2}{n}$$

Where e_t = forecast error for period t

n = number of periods of evaluation

Collaborative Planning, Forecasting, & Replenishment (CPFR)

What is CPFR?

It is a business practice that combines the intelligence of multiple trading partners in the planning & fulfillment of customer demands.

It links sales & marketing best practices, such as category management, to supply chain planning processes to increase availability while reducing inventory, transportation & logistics costs.

Collaborative Planning, Forecasting, & Replenishment (*Continued*)

Real value of CPFR comes from sharing of forecasts among firms rather than sophisticated algorithms from only one firm.

Does away with the shifting of inventories among trading partners that suboptimizes the supply chain.

CPFR provides the supply chain with a plethora of benefits but requires a fundamental change in the way that buyers & sellers work together.

Collaborative Planning, Forecasting, & Replenishment (*Continued*)

CPFR Benefits

- Strengthens partner relationships
- Provides analysis of sales and order forecasts
- Uses point-of-sale data, seasonal activity, promotions, to improve forecast accuracy
- Manages the demand chain and proactively eliminates problems before they appear
- Allows collaboration on future requirements and plans

Collaborative Planning, Forecasting, & Replenishment (*Continued*)

CPFR Benefits (continued)

- Allows collaboration on future requirements and plans
- Uses joint planning and promotions management
- Integrates planning, forecasting and logistics activities
- Provides efficient category management and understanding of consumer purchasing patterns

Collaborative Planning, Forecasting, & Replenishment (*Continued*)

CPFR Benefits (continued)

- Provides analysis of key performance metrics (e.g., forecast accuracy, forecast exceptions, product lead times, inventory turnover, percentage stockouts) to reduce supply chain inefficiencies, improve customer service, and increase revenues and profitability.

Useful Forecasting Websites

- Institute for Business Forecasting & Planning

  https://ibf.org/
- International Institute of Forecasters

  www.forecasters.org
- Forecasting Principles

  www.forecastingprinciples.com
- Stata (Data analysis & statistical software)

  www.stata.com/links/stat_software.html

Software Solutions

Forecasting Software simplifies the calculation processes and saves a great deal of time

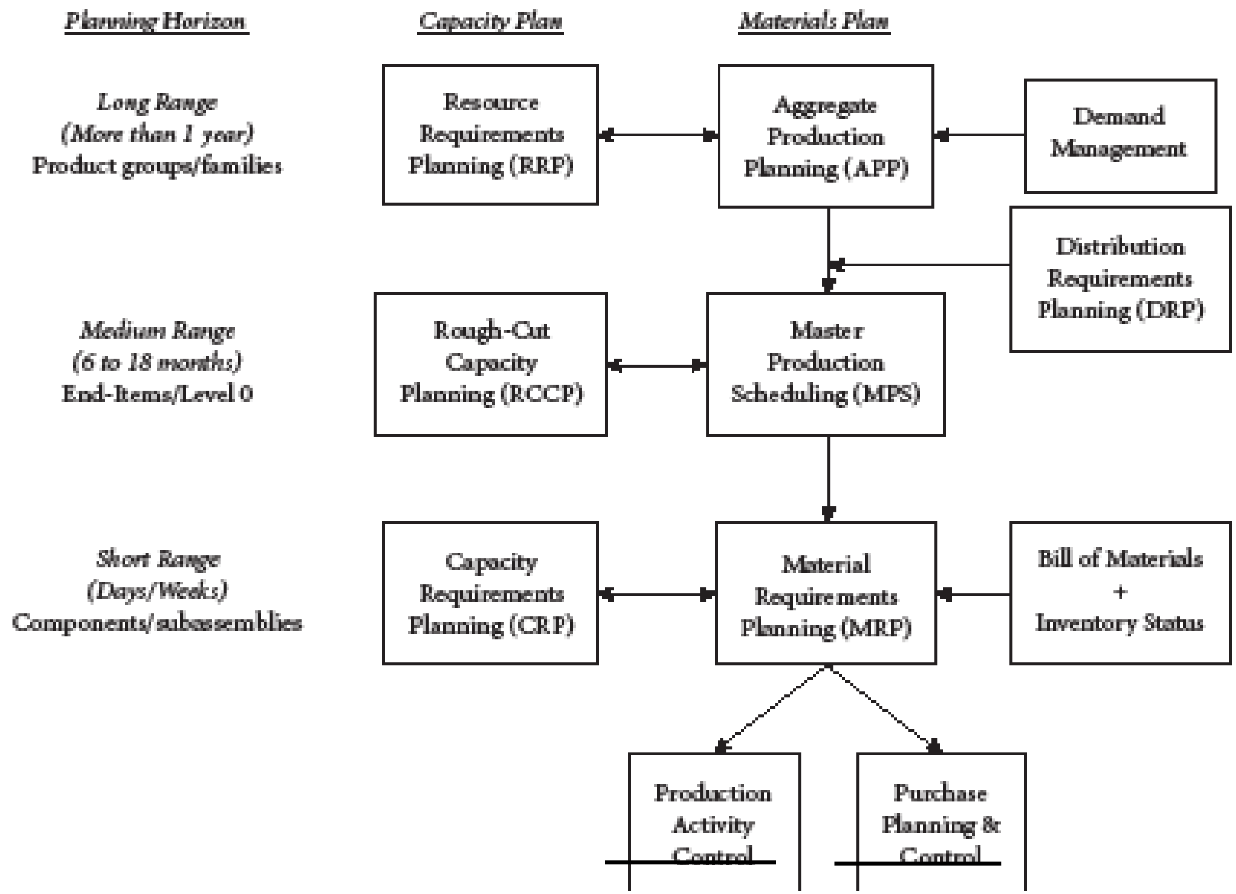
- Business Forecast Systems www.forecastpro.com
- John Galt www.johngalt.com
- Just Enough www.justenough.com
- SAS www.sas.com
- Avercast, LLC www.avercast.com

Operations Planning

Operations planning is usually hierarchical & can be divided into three broad categories:

- **Long-range – Aggregate Production Plan (APP)** usually covers a year or more, involves the construction of facilities & major equipment purchase
- **Intermediate –** plan spans six to eighteen months. Shows the quantity & timing of end items (i.e., master production schedule – MPS)
- **Short-range –** plan covers a few days to a few weeks. Detailed planning process for components & parts to support the master production schedule (i.e., materials requirement planning – MRP)

Operations Planning (*Continued*)



Operations Planning *(Continued)*

- **Material Requirements Plan** (MRP) is a system of converting the end items from the master production schedule into a set of time-phased component part requirements
- **Manufacturing resource planning (MRP II) –** combined MRP with master production scheduling, rough-cut capacity planning, capacity requirement planning, and other operations planning software modules
- **Enterprise requirements planning (ERP) -** is an extension of MRP-II
- **Distribution requirement planning (DRP) -** describes the time-phased net requirements from warehouses & distribution centers. Links production with distribution planning

Aggregate Production Plan

Hierarchical planning - process that translates annual business plans & demand forecasts into a production plan for a product family (products that share similar characteristics) in a plant or facility leading to the Aggregate Production Plan (APP)

- Planning horizon of APP is at least one year & is usually rolled forward by three months every quarter
- Costs relevant to the aggregate planning decision include inventory, setup, machine operation, hiring, firing, training, & overtime costs

Aggregate Production Plan (*Continued*)

Basic Production Strategies :

Chase Strategy - Adjusts capacity to match demand. Firm hires & lays off workers to match demand. Finished goods inventory remains constant. Works well for make-to-order firms

- Generally produce one-of-a-kind, specialty products
- Generally require highly skilled labor
- Can be problematic when highly skilled workers are needed in a tight labor market

Aggregate Production Plan *(Continued)*

Basic Production Strategies :

Level Strategy - Relies on a constant output rate while varying inventory & backlog according to fluctuating demand. Firm relies on fluctuating finished goods & backlogs to meet demand. Works well for make-to-stock firms

- Inventory carrying and stockout costs are major cost concerns
- This strategy works well when highly skilled workers are needed in a tight labor market

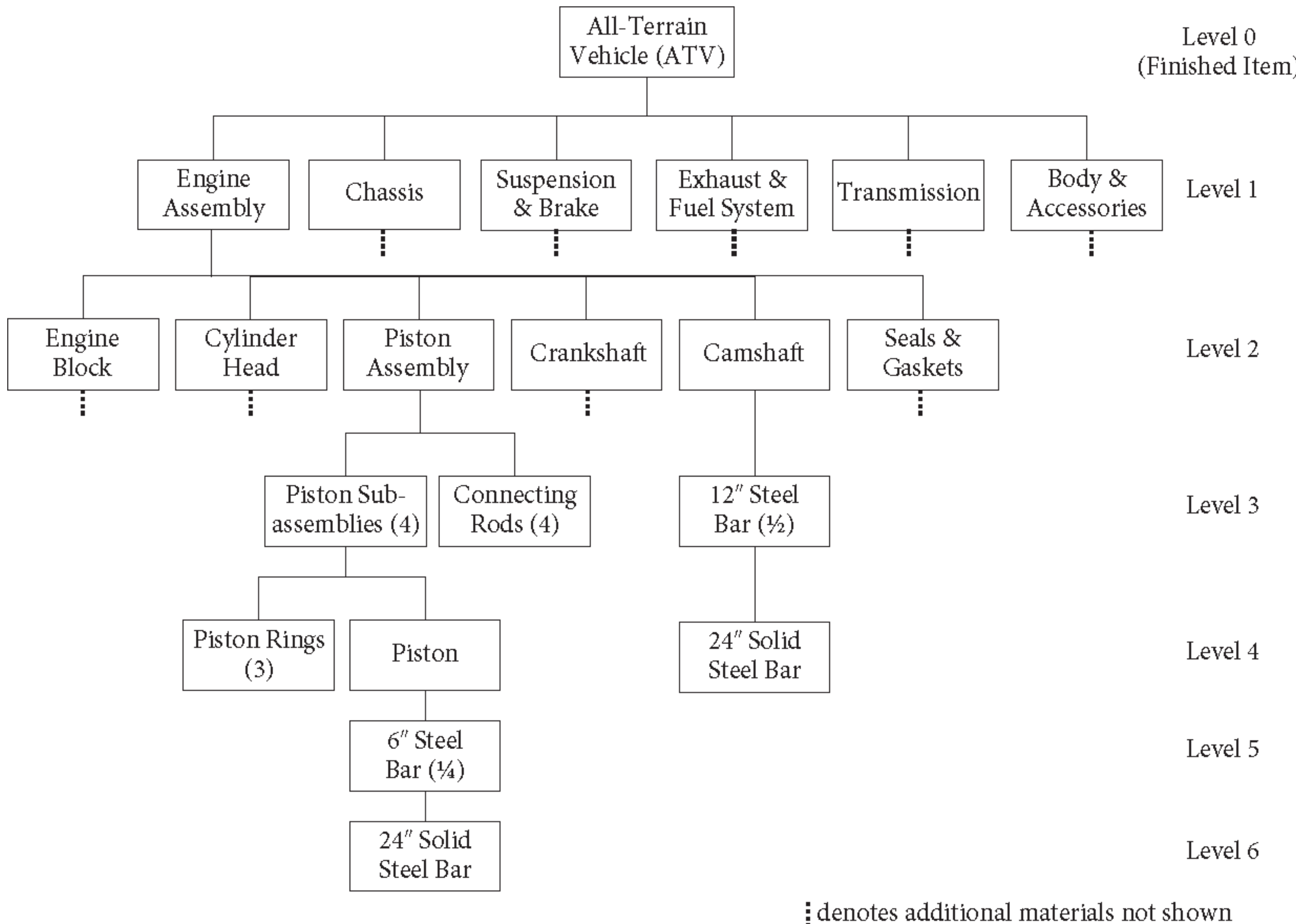
Aggregate Production Plan *(Continued)*

Basic Production Strategies :

Mixed Production Strategy - Maintains stable core workforce while using other short-term means, such as overtime, subcontracting & part time helpers to manage short-term demand

- Complementary products (with different demand cycles) may be produced
- Additional shift may be scheduled
- This strategy works well with firms producing multiple products

The Bill of Materials (*Continued*)



Material Requirements Plan (*Continued*)

Example 6.2

The production schedule for the ATV corporation is obtained from the MPS (table 6.4) and inventory status shows that 30 units of Model A are available at the beginning of the period. The parent-component relationships and planning factors are available in the BOM (figure 6.4). Assuming the following lot sizes (Q), lead times (LT), and safety stocks (SS), the MRP computations follow.

Material Requirements Plan *(Continued)*

Example 6.2

Model A ATV—Level 0		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements		10	10	20	0	20	0	0	20
Scheduled Receipts			10						
Projected On-hand Inventory	30	20	20	20	20	20	20	20	20
Planned Order Releases		20		20			20		
Q = 10; LT = 2; SS = 15									

× 1 × 1 × 1

Engine Assembly—Level 1		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements		20		20			20		
Scheduled Receipts		20							
Projected On-hand Inventory	2	2	2	0	0	0	0	0	0
Planned Order Releases		18			20				
Q = LFL; LT = 2; SS = 0									

× 1 × 1

Piston Assembly—Level 2		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements		18			20				
Scheduled Receipts		20							
Projected On-hand Inventory	10	12	12	12	22	22	22	22	22
Planned Order Releases				30					
Q = 30; LT = 1; SS = 10									

× 4

Connecting Rods—Level 3		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements				120					
Scheduled Receipts									
Projected On-hand Inventory	22	22	22	52	52	52	52	52	52
Planned Order Releases			150						
Q = 50; LT = 1; SS = 20									

Capacity Planning

Capacity – refers to a firm's labor and machine resources

Resource Requirement Planning (RRP) - a long-range capacity planning module, checks whether aggregate resources are capable of satisfying the aggregate production. Resources considered include gross labor hours & machine hours

Medium-range capacity plan, or rough-cut capacity plan (RCCP) - used to check feasibility of MPS. Converts MPS from production needed to capacity required, then compares it to capacity available

Capacity requirement planning (CRP) - a short-range capacity planning technique that is used to check the feasibility of the material requirements plan

Capacity Planning *(Continued)*

Lead capacity strategy – a proactive approach that adds or subtracts capacity in anticipation of future market conditions and demand

Lag capacity strategy – a reactive approach that adjusts its capacity in response to demand

Match or tracking capacity strategy - a moderate strategy that adjusts capacity in small amounts in response to demand and changing market conditions

Distribution Requirements Planning (DRP)

Distribution requirements planning (DRP) - a time-phased finished good inventory replenishment plan in a distribution network

- DRP is a logical extension of the MRP system & ties physical distribution to manufacturing planning and control system
- MRP operates in a dependent demand situation, whereas the DRP operates in an independent demand setting

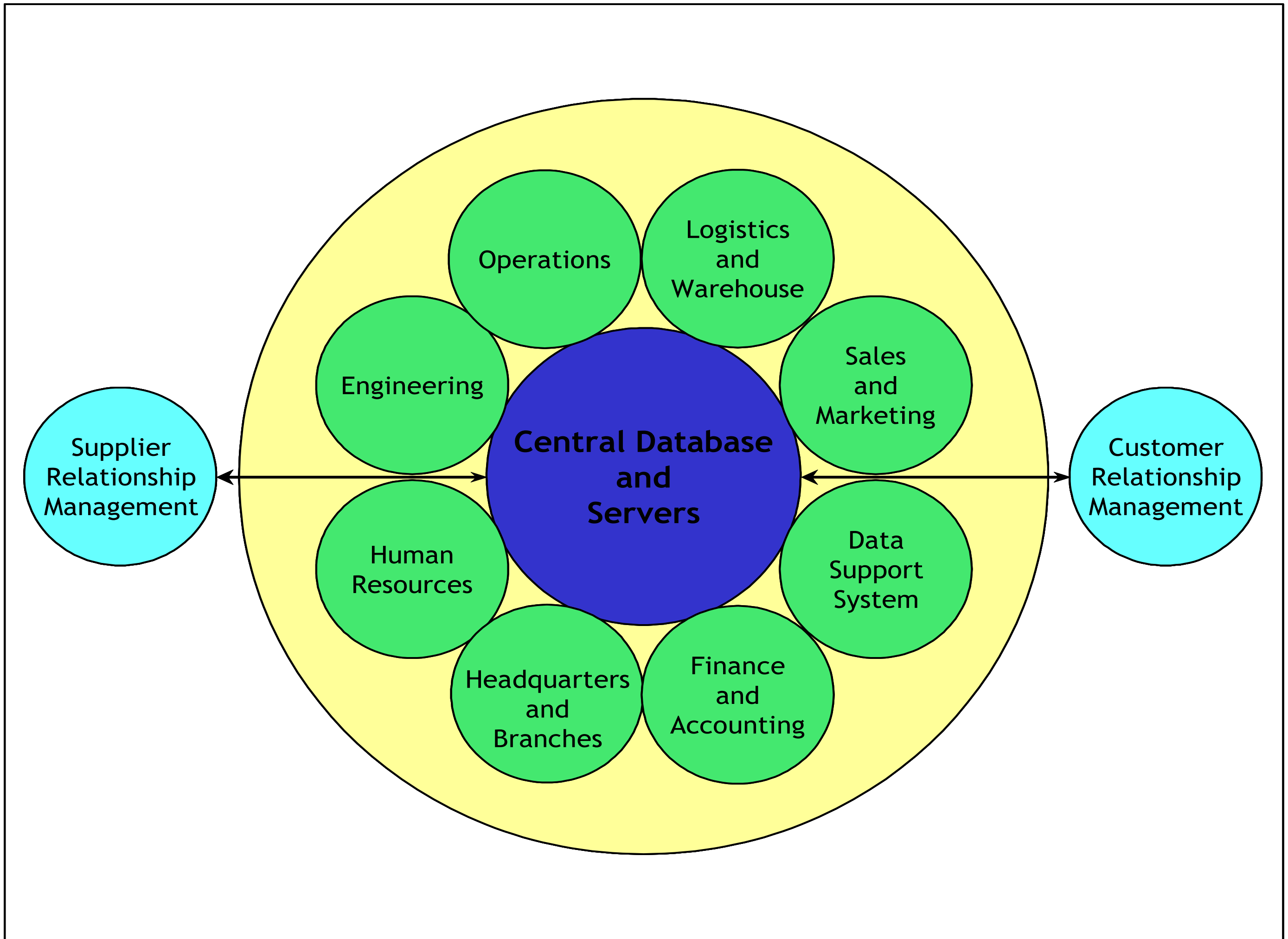
Development of ERP Systems

Enterprise Resource Planning Systems (ERP) - integrates the internal operations of an enterprise with a common software platform and centralized database system

- With a shared, centralized database system, ERP is capable of automating business processes rapidly and accurately
- ERP provides means for supply chain members to share information so that scarce resources can be fully utilized to meet demand, while minimizing supply chain inventories

Development of ERP Systems (*Continued*)

Figure 6.6 - Generic ERP System



Introduction

- Inventory can be one of the most expensive assets of an organization
- Inventory may account for more than 10% of total revenue or total assets
- Management must reduce inventory levels yet avoid stockouts and other problems
- Effective inventory management is important to both manufacturers and service organizations
- Excessive inventory is a sign of poor inventory management

Dependent & Independent Demand

Inventory management models –

Generally classified as dependent demand and independent demand models

- **Dependent Demand –**

  Describes the internal demand for parts based on the demand of the final product in which the parts are used. Subassemblies, components, & raw materials are examples of dependent demand items.

- **Independent Demand –**

  The demand for final products & has a demand pattern affected by trends, seasonal patterns, & general market conditions.

Functions and Basic Types of Inventory

- The primary functions of inventory are to –
  - **Buffer from uncertainty in the marketplace &**
  - **Decouple dependencies in the supply chain (e.g., safety stock)**

- Four broad categories of inventories
  - **Raw materials- unprocessed purchase inputs.**
  - **Work-in-process (WIP)- partially processed materials not yet ready for sales.**
  - **Finished goods- products ready for shipment.**
  - **Maintenance, repair & operating (MRO)- materials used in production (e.g., cleaners & brooms).**

Concepts and Tools of Inventory Management (*Continued*)

ABC Inventory Control System

Determines which inventories should be counted & managed more closely than others

- Groups inventory as A, B, & C Items
  - **A items** are given the highest priority with larger safety stocks. A items account for approximately 20% of the total items & about 80% of the total inventory cost
  - **B items** account for the other about 40% of total items & 15% of total inventory cost.
  - **C items** have the lowest value and hence lowest priority. They account for the remaining 40% of total items & 5% of total inventory cost.

Inventory Models

Fixed Order Quantity Models

- **Economic Order Quantity Model**
- **Quantity Discount Model**
- **Economic Manufacturing Quantity Model**

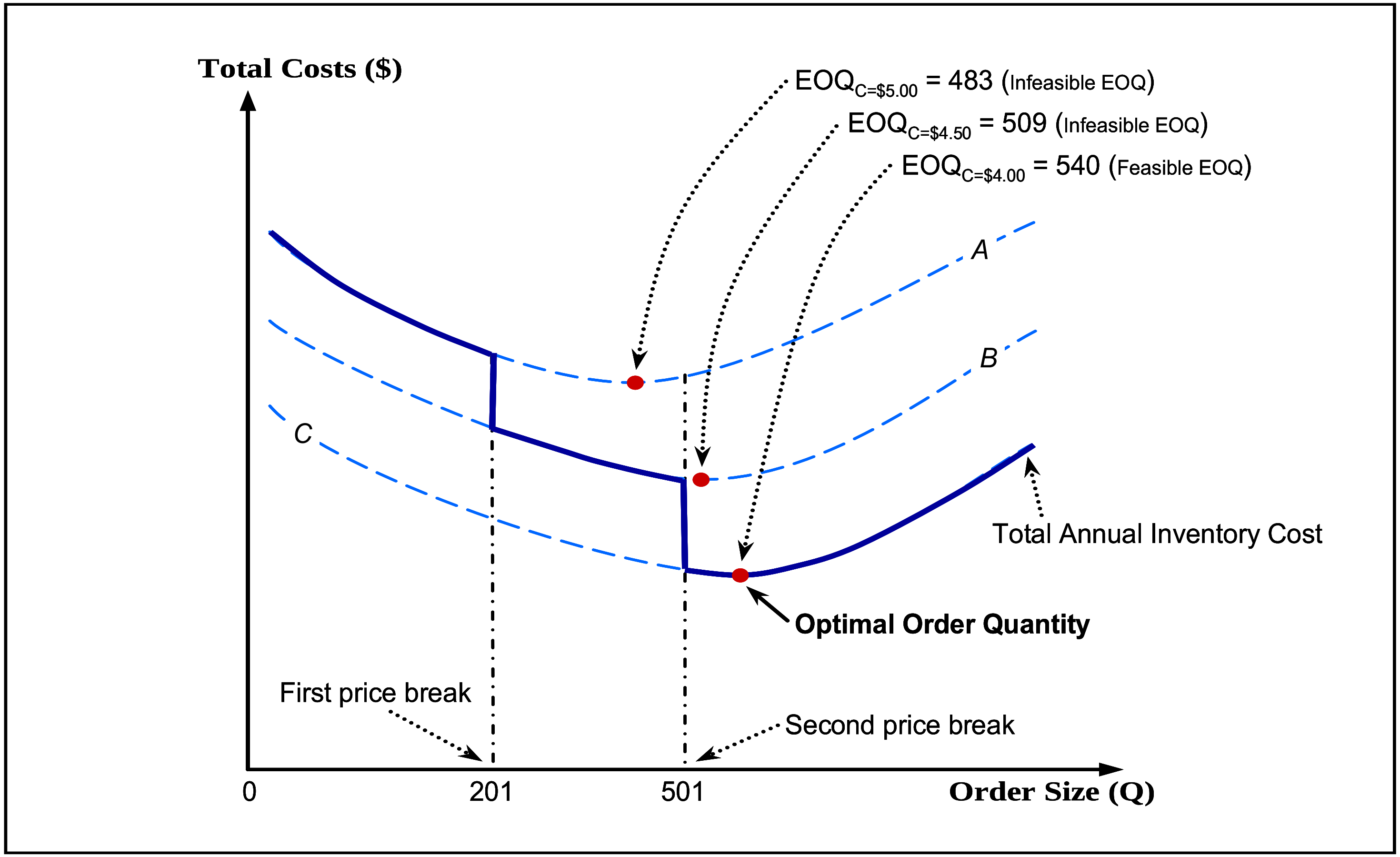
These models use fixed parameters to derive the optimum order quantity to minimize total inventory cost

Inventory Models *(Continued)*

- **Economic Order Quantity formula**

$$\text{EOQ} = \sqrt{\frac{2RS}{kC}}$$

Quantity Discount Model

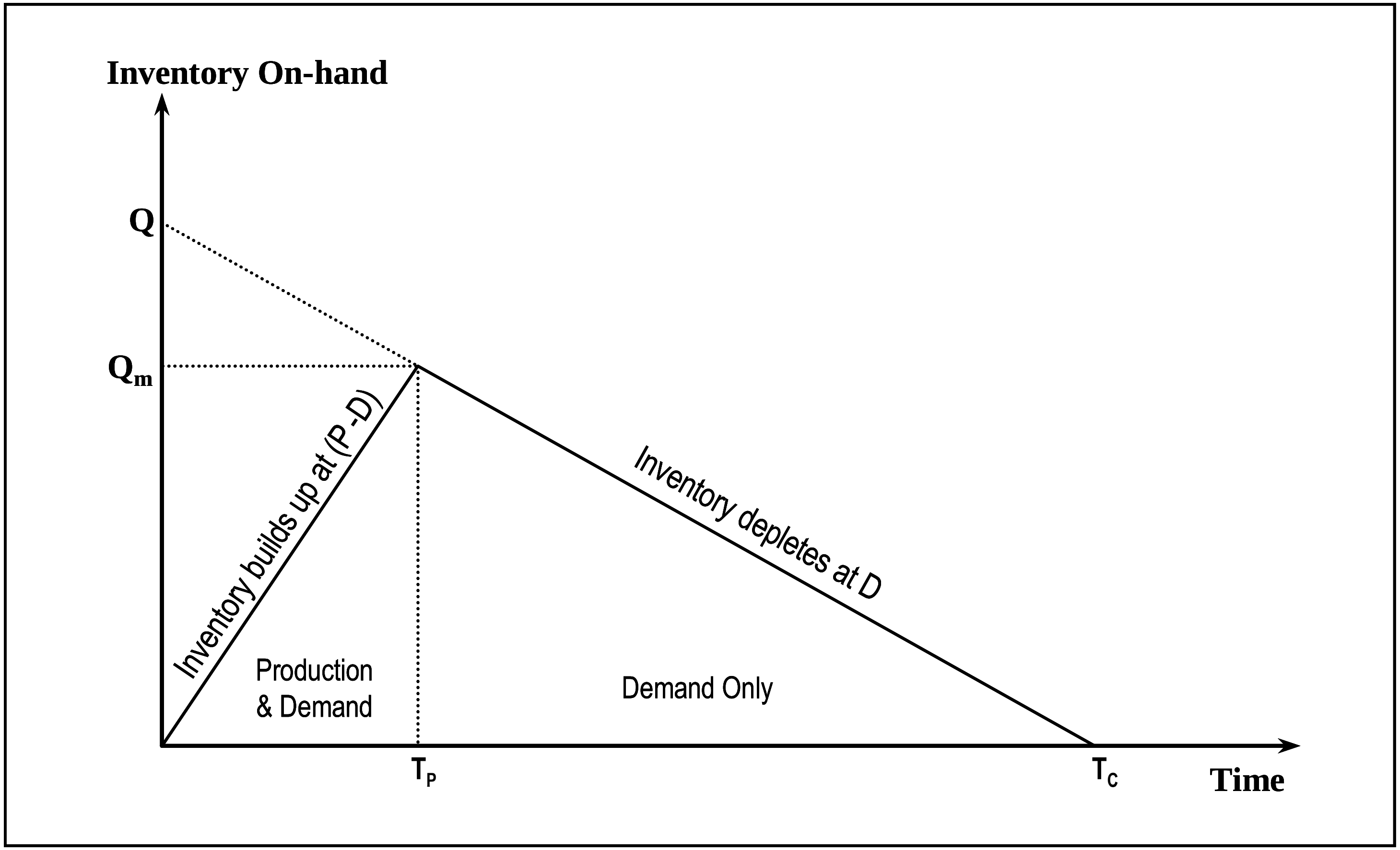


Inventory Models (*Continued*)

- The **Economic Manufacturing Quantity Model** or **Production Order Quantity Model**
  - Relaxes the instantaneous replenishment assumption by allowing usage during production or partial delivery.
  - The EMQ model is especially appropriate for a manufacturing environment with simultaneous manufacture and consumption
  - Inventory builds up gradually during the production period rather than at once as in the EOQ model.

Inventory Models (*Continued*)

The EMQ Model



Inventory Models *(Continued)*

- The Statistical **Reorder Point (ROP)**
  - The lowest inventory level at which a new order must be placed to avoid a stockout.
  - Demand and delivery lead time are never certain and require safety stock.
- The models used under uncertainty are –
  - Statistical ROP with Probabilistic Demand and Constant Lead Time
  - The Statistical ROP with Constant Demand and Probabilistic Lead Time
  - The Statistical ROP when Demand and Lead Time are both Probabilistic

Inventory Models (*Continued*)

- **The Continuous Review and The Periodic Review Inventory Systems**
  - Order quantity & ROP models assume that the physical inventory is precisely known at every point in time
  - Reality shows that stock records and actual quantity are different & requires continuous review of inventory to determine when to reorder
  - A Continuous Review System is costly to conduct but requires less safety stock than the
  - The Periodic Review System, which reviews physical inventory at specific points in time and requires higher level of safety stock

Inventory Models (*Continued*)

The Continuous Review System

- (s, Q) continuous review policy: orders the same quantity, Q, when physical inventory reaches the reorder point, s
- (s, S) continuous review policy: When current inventory reaches or falls below the reorder point, s, sufficient units are ordered to bring the inventory up to a pre-determined level, S.

Inventory Models (*Continued*)

The Periodic Review System

- *(nQ, s, R) periodic review policy*: If at the time of inventory review, the physical inventory is equal to or less than the reorder point, s, the quantity, nQ, is ordered to bring the inventory up to the level between s and (s + Q).
- *(S, R) periodic review policy*: At each review time, a sufficient quantity is ordered to bring the inventory up to a pre-determined maximum inventory level, S.
- (s, S, R) policy: If at the time of inventory review, the physical inventory is equal to or less than the reorder point, s, a sufficient quantity is ordered to bring the inventory level up to the maximum inventory level, S.

PERFORMANCE MEASUREMENT ALONG THE SUPPLY CHAIN

Introduction

“You can’t improve what you don’t measure”

- Designing standards and monitoring them can provide much better information for decision-making purposes.
- Adding several tiers of suppliers & customers complicates performance measurement.
- Achieving adequate performance and then continually improving on those measures are what firms aim toward.
- Performance measures must be visible & communicated to all members of the SC.

Viewing the SC as a Competitive Force

Understanding End Customers

Supply chains need to look at each segment of the market they serve & determine the needs of those customers.

- Variety of products required
- Quantity & delivery frequency needed
- Sustainability level desired
- Product quality desired
- Price of the products

Viewing the SC as a Competitive Weapon (*Continued*)

Understanding SC Partner Requirements

Supply chain strategies must consider the potential trade-offs existing between:

- Cost
- Quality
- Sustainability
- Service

Viewing the SC as a Competitive Weapon (*Continued*)

Adjusting SC Member Capabilities

- SC members audit their capabilities & partners' to determine consistency with needs of end customers & SC
- Firms & their partners must continually reassess performance with respect to requirements
- The best SC performers are more responsive to customer needs, quicker to anticipate changes in the markets, & control costs much better

Traditional Performance Measures

Traditional Performance Measures

- Traditional cost-based information does not reflect the underlying performance of an organization’s productive systems; costs & profits can be hidden or manipulated
- Decisions to maximize current stock prices do not necessarily reflect that the firm is performing well
- Financial performance measures, while important, cannot adequately capture a firm’s ability to excel in these areas

Traditional Performance Measures (*Continued*)

Use of Organization Costs, Revenue, & Profitability Measures

Problems associated with using costs & profits to gauge performance –

- Uncontrollable environmental forces (e.g., windfall profits that occur when prices rise due to supply interruptions)
- Accurate attribution of cost, revenue, or profit contributions to the various functional or business units

Traditional Performance Measures *(Continued)*

Use of Performance Standards & Variances

Establishing standards for comparison purposes can be troublesome

- Employees & managers do whatever it takes to reach the goal
- Shoddy work & “Cooking” the books

Traditional Performance Measures (*Continued*)

Use of Performance Standards & Variances (*Continued*)

Traditional Performance Measures *(Continued)*

Productivity & Utilization Measures

Examples

- Overall total productivity measure

$$\frac{\text{output}}{\text{costs of (labor + capital + energy + material)}}$$

- Single-factor productivity measure

$$\frac{\text{output}}{\text{cost of labor}}$$

Traditional Performance Measures (*Continued*)

Productivity & Utilization Measures

These measures are useful but have the same problems as revenues, costs, & profits

- Productivity decisions may actually increase costs & reduce quality
- Tendency to continue producing & adding to inventory to keep machines & people busy
- Less time is spent doing preventive maintenance & training for greater performance & profits in future
- Traditional measures favor the short-term

World-Class Performance Measurement Systems

Developing World Class Performance Measures

- Identify the firm's strategic objectives.
- Develop an understanding of each functional area's set of requirements for achieving the strategic objectives.
- Design and document performance measures for each functional area that adequately track each required capability.
- Assure the compatibility and strategic focus of the performance measures to be used.

World-Class Performance Measurement Systems (*Continued*)

Developing World Class Performance Measures
(continued)

- Implement the new performance monitoring system.
- Identify internal and external trends likely to affect firm and functional area performance over time.
- Periodically re-evaluate the firm's performance measurement system as these trends and other environmental changes occur

World-Class Performance Measurement Systems (*Continued*)

Table 14.1 World-Class Performance Measures	
Capability Areas	**Performance Measures**
Quality	1. No. of defects per unit produced and per unit purchased 2. No. of product returns per units sold 3. No. of warranty claims per units sold 4. No. of suppliers used 5. Lead time from defect detection to correction 6. No. of workcenters using statistical process control 7. No. of suppliers who are quality certified 8. No. of quality awards applied for; No. awards won

World-Class Performance Measurement Systems (*Continued*)

Table 14.1	World-Class Performance Measures
Capability Areas	**Performance Measures**
Cost	1. Scrap or spoilage losses per workcenter 2. Average inventory turnover 3. Average setup time 4. Employee turnover 5. Avg. safety stock levels 6. No. of rush orders required for meeting delivery dates 7. Downtime due to machine breakdowns

World-Class Performance Measurement Systems

Table 14.1 World-Class Performance Measures	
Capability Areas	**Performance Measures**
Customer Service	*Flexibility* 1. Average number of labor skills 2. Average production lot size 3. No. of customized services available 4. No. of days to process special or rush orders *Dependability* 1. Average service response time or product lead time 2. % of delivery promises kept 3. Avg. no. of days late per shipment 4. No. of stockouts per product 5. No. of days to process a warranty claim 6. Avg. number of hours spent with customers by engineers *Innovation* 1. Annual investment in R&D 2. % of automated processes 3. No. of new product or service introductions 4. No. of process steps required per product

SC Performance Measurement Systems

Performance measurement systems must –

- Link SC trading partners to achieve breakthrough performance in satisfying the end users
- Overlay the entire supply chain to assure that all contribute to supply chain strategy

In a successful chain, members jointly agree on a SC performance measurement system

SC Performance Meas. Systems (*Continued*)

Environmental sustainability

- Addressing the need for protecting the environment & reducing greenhouse gas emissions as well business & consumer needs

Green supply chain management (GSCM)

- Sharing of environmental responsibility along the SC such that sound environmental practices predominate, & adverse global environmental effects are minimized.

Carbon footprint

- Supply chains evaluate design configurations and various options for reducing total carbon emissions

SC Performance Meas. Systems (*Continued*)

Supply Chain Performance Measures

- *Total SCM costs* are the costs to process orders; purchase & manage inventories; & information systems
- *SC cash to cash cycle time is the a*vg. # of days between paying for materials & getting paid by SC partners
- *SC production flexibility* is the avg. time required to provide an unplanned 20% increase in production
- *SC delivery performance* is the avg. % of orders filled by requested delivery date

SC Performance Meas. Systems *(Continued)*

Supply Chain Performance Measures *(continued)*

- *SC perfect order fulfillment performance* is the average % of orders that arrive on time, complete, & undamaged.
- *Supply chain e-business performance* is the avg. % of electronic orders received for all SC members.
- *Supply Chain Environmental Performance* is the % of SC w/ISO 14000 partners, avg. % env. goals met, avg. # of policies adopted to reduce greenhouse gas emissions, or avg. % of carbon footprints offset

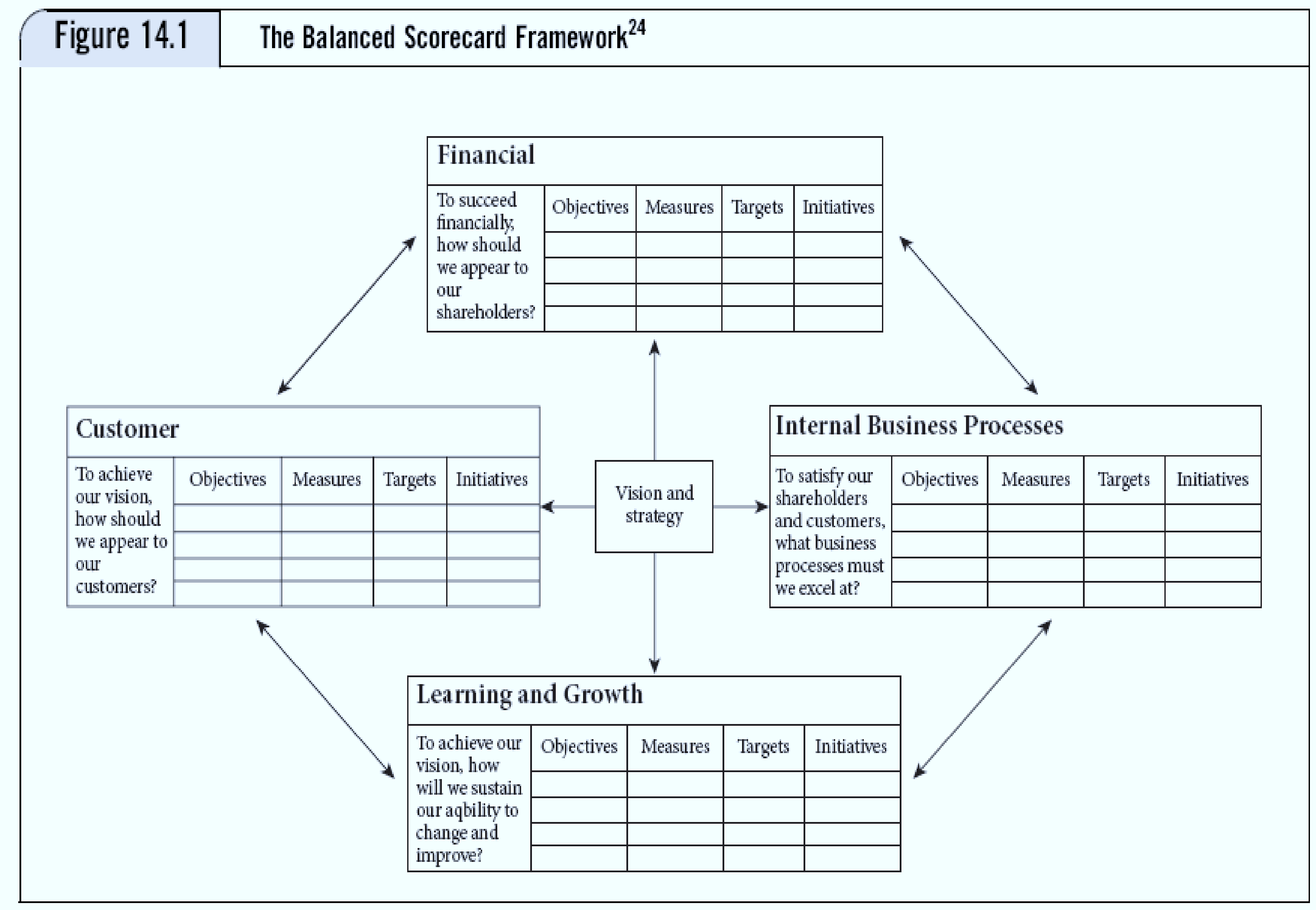
The Balanced Scorecard

Kaplan & Norton created BSC to align an organization's performance measures with its strategic plan & goals. The BSC framework consists of four perspectives –

- Financial perspective
- Internal business process perspective
- Customer perspective
- Learning & growth perspective

Also referred to as scorecarding

The Balanced Scorecard (*Continued*)



The Balanced Scorecard *(Continued)*

Web-Based Scorecards & Dashboards

- Web-based software applications used to design scorecards, which also link via the Web to a firm's enterprise software system.
- Provide managers a way to see real-time progress toward organizational milestones & help to ensure that decisions remain in sync with the firm's overall strategies.

Supply Chain Operations Reference (SCOR) Model

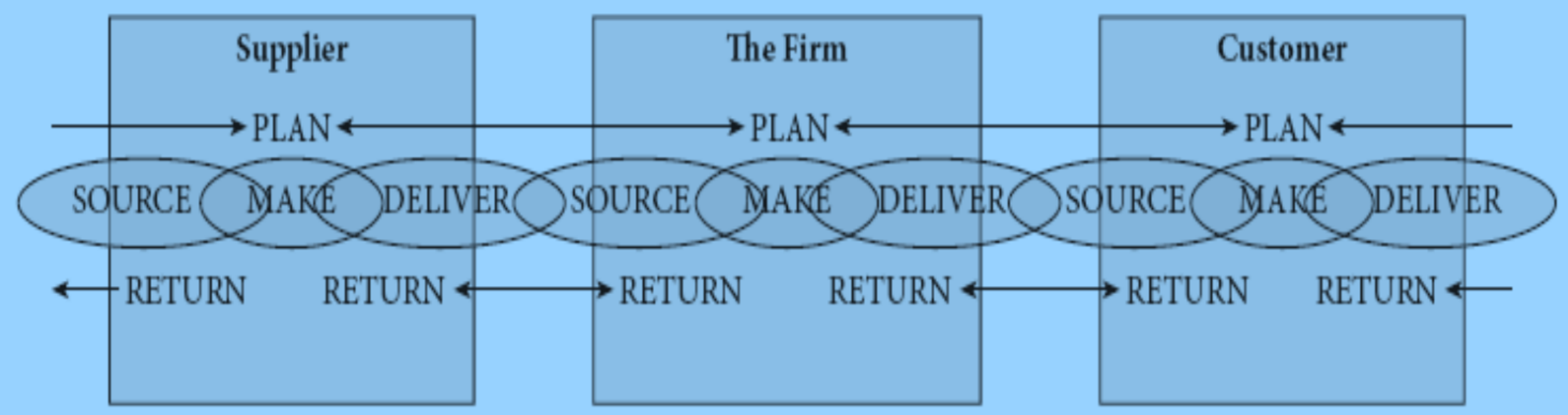
SCOR model developed by the Supply Chain Council (now CSCMP) for SCM diagnostic benchmarking & process improvement

The SCOR model separates supply chain operations into 6 process categories –

- Plan
- Source
- Make
- Deliver
- Return
- Enable

SCOR Model (*Continued*)

Figure 14.2 The SCOR Model Linkages



SCOR Model *(Continued)*

Table 14.2 SCOR Performance Categories and Attributes	
Performance Category	**Performance Attribute**
Reliability	1. On-time delivery performance 2. Order fill rates 3. Order accuracy rates
Responsiveness	1. Order lead times or speed
Agility	1. Response times for unforeseen events 2. Production flexibility
Cost	1. Supply chain management and logistics costs 2. Cost of goods sold 3. Warranty and returns processing costs
Asset Management	1. Cash-to-cash cycle time 2. Inventory days of supply 3. Asset turns

SCOR Model *(Continued)*

Companies generally use SCOR-based benchmarking to:

- Set reasonable performance goals based on the SCOR model
- Calculate performance gaps against a global database
- Develop company-specific roadmaps for supply chain competitive success

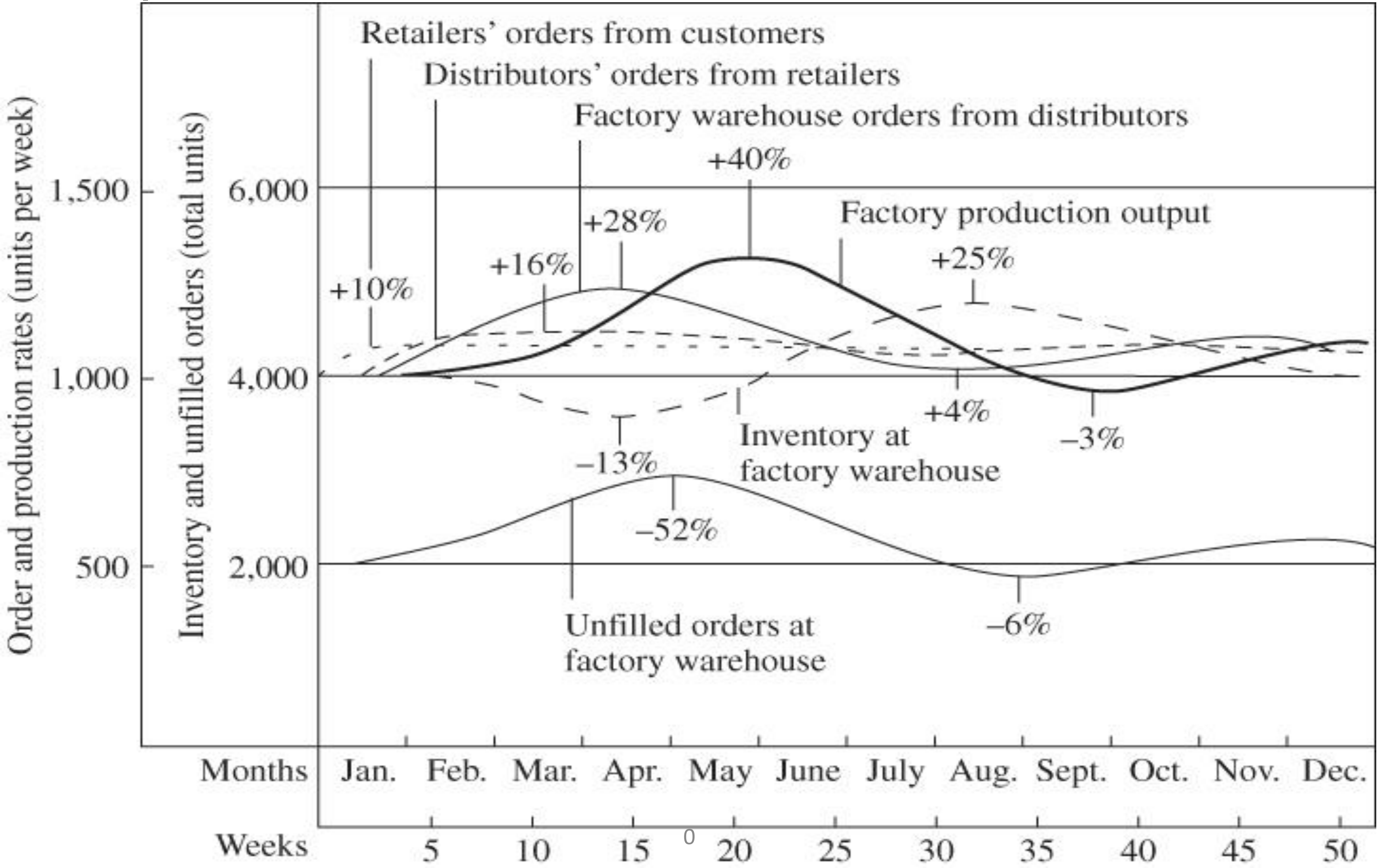
Bullwhip Effect

Bullwhip Effect

- **Slight changes in actual demand** create problems
- Partners build “**just in case**” inventories
- **Lack of trust** among partners
- Stockpilling result in huge cost
- The manufacturers **can not plan production**
- **Cannot order material from suppliers**

Bullwhip Effect

- **Bullwhip effect showing requirements error amplification between supply chain partners**



Avoiding the Sting of the Bullwhip

- **Information sharing** is a must
- **Trust and agreements**
- **Collaboration and partnership**
- **Value co-creation** amongst the stakeholders (both internal and external stakeholders)

Information Technology Solutions to the Bullwhip Effect

- Automate order taking
- Use EDI/Internet
- Web based ordering; intelligent agents
- Electronic payments
- Make-to-order (JIT)
- Tracking systems
- Supplier monitor and manage inventories
- Information from POS to suppliers
- Electronic trading markets and exchanges

Retailing

Includes all activities involved in selling goods or services directly to final consumers.

Store Brands

- With the increase in size and buying strength of retailers, companies are forced to now customize products for them. These are known as store brands. They may compete at the store with the company's own brands.

What is wholesaling?

- It includes all activities involved in selling goods and services for resale or business use. They are the intermediaries between manufacturers and retailers.

Trends in the manufacturing sector emerging from globalisation

- Global competition
- Competitors, partners and customers from around the world
- Global sourcing
- Global presence
- Global value chains resulting in increasing complexity and competition
- Global access to knowledge and new technologies
- High level of customer awareness and expectation
- Rapid pace of technological change
- Fast rate of product commoditisation
- SCM expertise and innovation are preconditions for business success

Outsourcing

- The transfer of to a third party of the management & delivery of a process previously performed by the company itself
- Requiring:
  - Service Level Agreements (SLAs)
  - Order winners and qualifiers
  - Supplier development
- Creating:
  - Virtual organisations

Reasons for manufacturing outsourcing

- Reduce direct and indirect costs
- Reduce capital costs
- Reduce taxes
- Reduce logistics costs
- Overcome tariff barriers
- Provide better customer service
- Spread foreign exchange risks
- Share risk
- Build alternative supply sources
- Pre-empt potential competitors
- Learn from local suppliers, foreign customers or competitors
- Gain access to world class capabilities or attract talent globally

Offshoring

- The transfer of specific processes to lower cost locations in other countries
  - Not the same as outsourcing
    - Outsourcing involves handing process ownership over to a third party
    - In offshoring, the company may still own and control the process itself in the lower cost location

Reasons for offshoring

- Lower costs in the offshoring region
- Less stringent regulatory controls in offshore region
- Deregulation of trades facilitates offshoring
- Lower communication and IT costs
- Improving Capabilities of many offshore regions

Intermodal transport

- Where freight moves within a loading unit (known as an ITU – internodal transport unit), this unit may move upon a number of different transport modes
- But the freight remains within the unit at all times
- Various types of ITUs:
  - Standard sized containers (typically 20 and 40 feet in length)
  - ‘Igloo’ containers used in air freight

Key global security initiatives

- IMO International Ship and Port Facility Security (ISPS) Code
- US Customs-Trade Partnership Against Terrorism (C-TPAT)
- US Container Security Initiative (CSI)
- European Union Authorised Economic Operator (AEO)
- ISO 28000, the new security standard for supply chain security

An overview of contemporary transport security initiatives

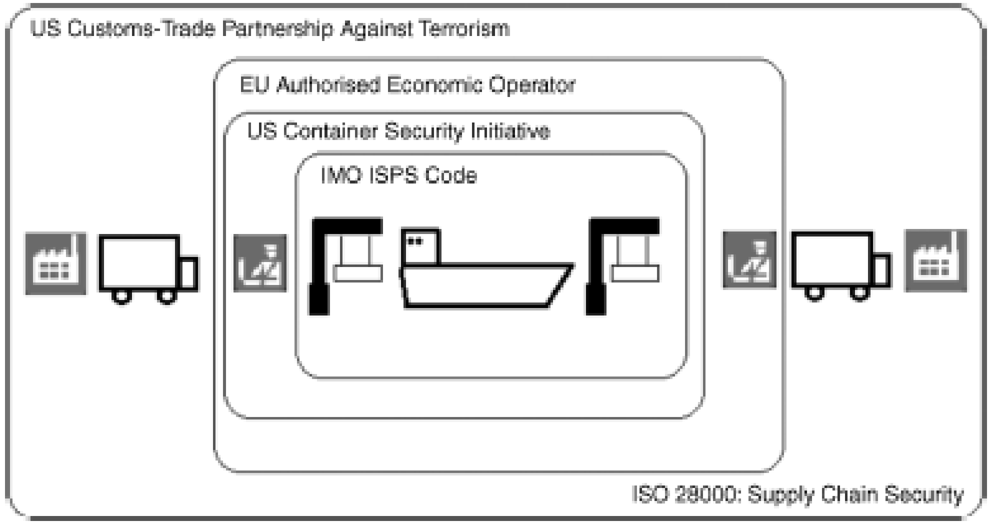


Figure 7.1 An overview of contemporary transport security initiatives (Source: Amended from OECD, 2003)[7]

Transport security technology

- Access control
- Biometrics
- Detection systems
  - CCTV
  - Motion detector systems
  - X-ray & gamma ray detection systems

Classifying logistics companies

- A move away from own-account transportation to third-party transportation
  - Creating logistics service providers (LSPs)
    - Hauliers or trucking companies
    - Freight forwarders
    - Non-vessel-owning common carriers (NVOCCs)
    - Couriers
    - Integrators (e.g. FedEx, UPS and DHL)

LSPs versus 3PLs

- Considerable overlap between the terminology
- All companies that provide logistics services are LSPs
- LSPs that provide multiple logistics services, often integrated, are third party logistics providers (3PLs)

Typical 3PL services

- Transportation
- Warehousing
- Pick and pack
- Light manufacturing
- Vendor managed inventory (see chapters 3 & 12)
- Customs clearance
- Trade financing
- Managing reverse logistics
- Parts distribution
- Inventory management

Fourth party logistics (4PLs)

- Offering total outsource supply chain solutions
- Originally trademarked by Accenture in 1996
  - A supply chain integrator that assembles and manages the resources, capabilities and technology of its own organisation, with those complementary service providers, to deliver a comprehensive supply chain solution
- The line between 3PL and 4PL is now being blurred as 3PLs now offer 4PL type solutions

Warehousing in Global Supply Chains

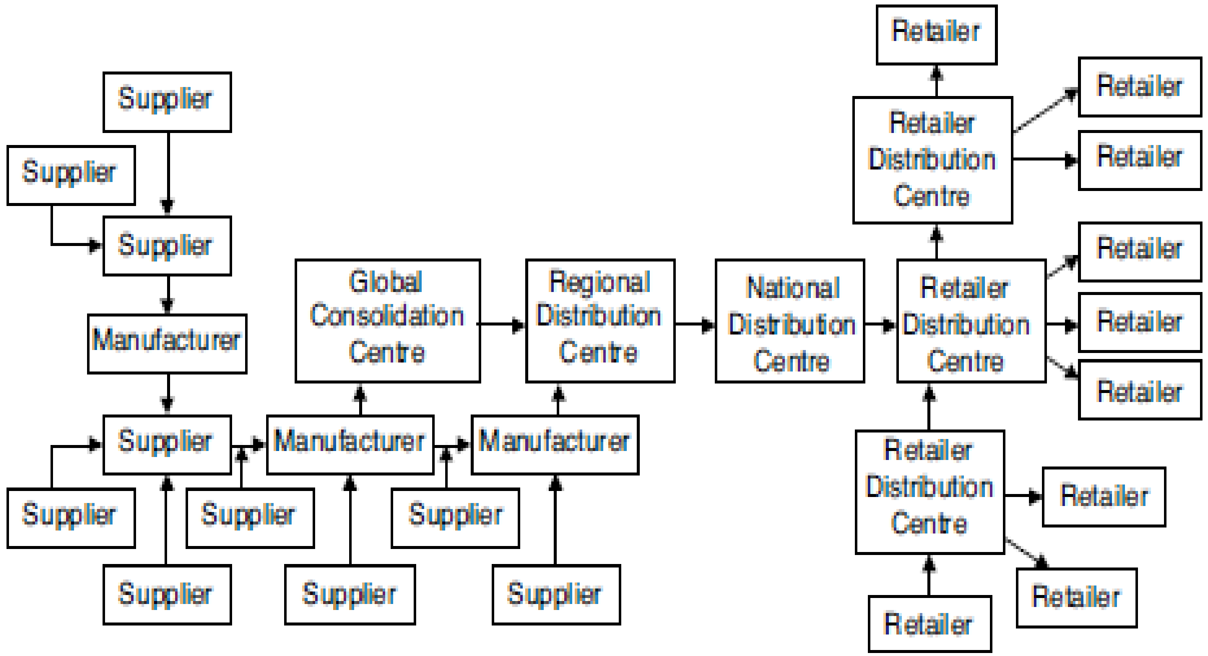


Figure 11.1 A typical map of warehousing operations in a global supply chain

WMS Information Inputs and Outputs

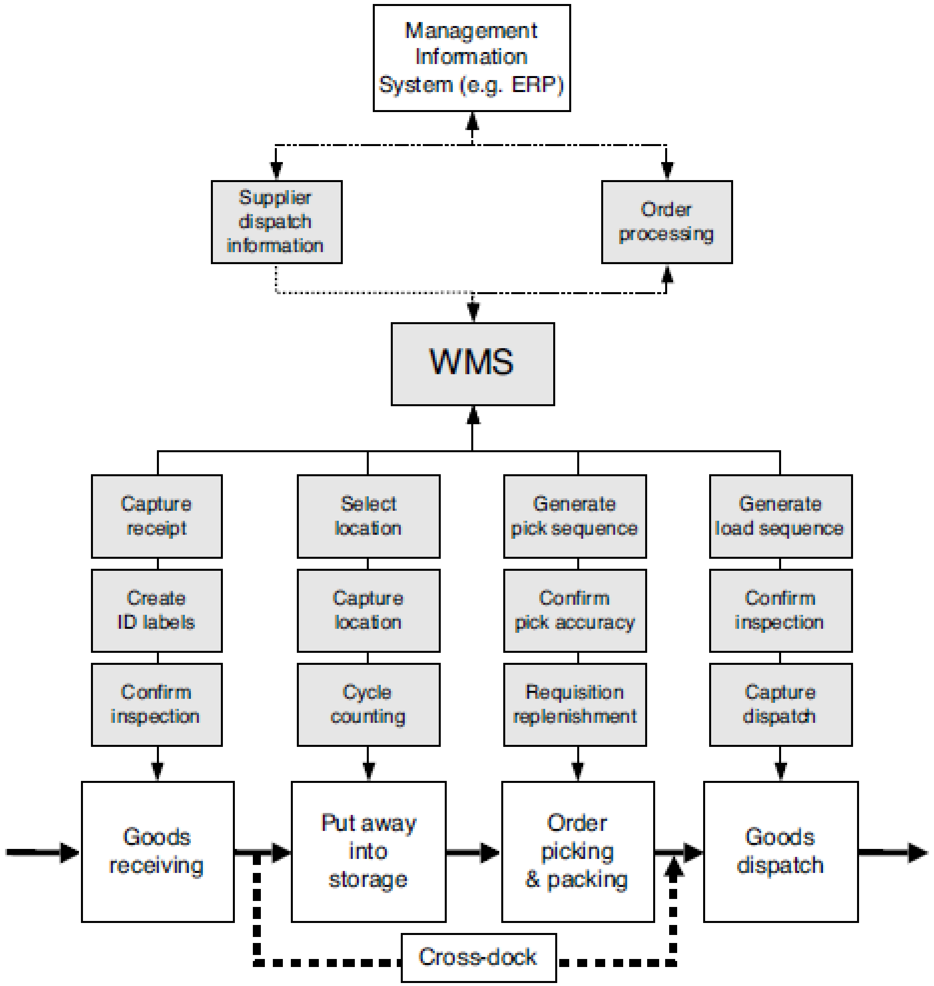


Figure 11.5 WMS information inputs and outputs

Role of Information in Global Supply Chains

- Key drivers of developing sophisticated supply chain information technologies:
  - Information complexity
  - Proliferation
  - Diffusion
  - Velocity
  - Accuracy

Information Visibility and Transparanecy

- **Information visibility** is the ability to see information at the various points across the supply chain as and when required.

- Barriers of gaining information visibility are:
  - Cultural
  - Financial
  - Technical
  - Organisational

Benefits of Information Visibility

- Customer-oriented operations
- Time compression
- Reduced schedule variability
- Shorter planning periods
- Consistent partnerships
- Supply chain synchronisation and coordination
- A single point control
- Integrated information systems

Information Technology Applications

- Electronic Data Interchange (EDI)
- Enterprise Resource Planning (ERP)
- Material Resource Planning (MRP)
- Collaborative Planning, Forecasting and Replenishment (CPFR)
- Vendor Managed Inventory (VMI)
- Warehouse Management Systems (WMS)

VMI

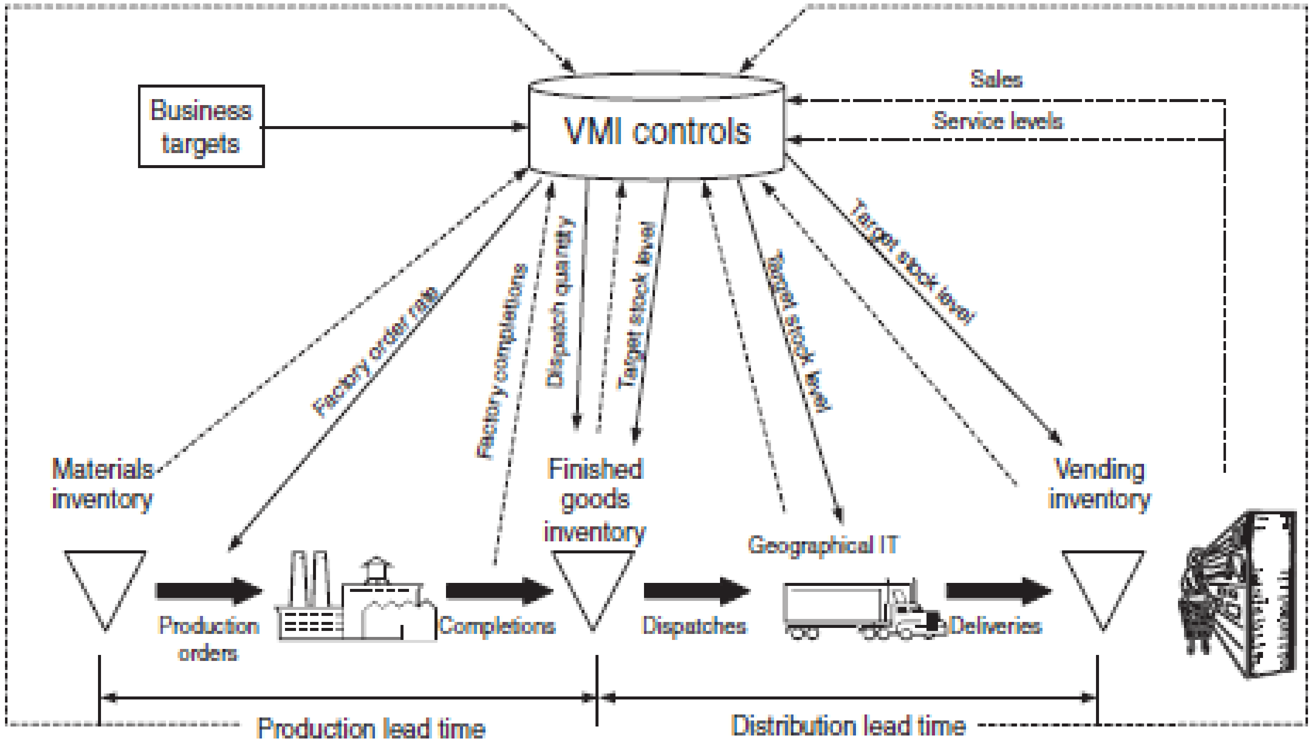


Figure 12.4 A simplified VMI scenario (Source: Adapted from Matthias *et al.*, 2005)[14]

Types of VMI in Supply Chains

Table 12.1 Types of vendor managed inventory in supply chains[15]

Configuration	Description of collaborative or vendor managed functions
Type 0	Traditional supply chain
Type I	Replenishment only
Type II	Replenishment and forecasting
Type III	Replenishment, forecasting and customer inventory management
Type IV	Replenishment, forecasting, customer inventory management and distribution planning

Definition of reverse logistics

- Reverse logistics can be defined as:

"The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing or creating value or proper disposal"

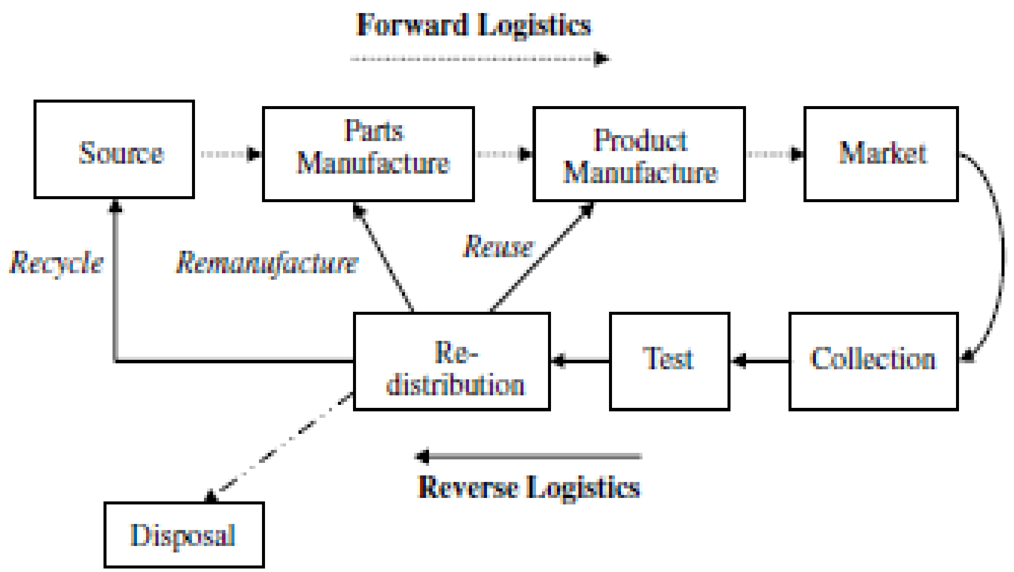


Figure 17.1 A generic reverse logistics system with recovery options

Motivations for reverse logistics

- Government Policy and Legislation
- Economic Considerations
- Environmental Considerations
- Shift Towards Buying Sets of Services

Recovery options in reverse logistics

- Reuse
  - Reuse refers to a process in which the recovered product is used again for a purpose similar to the one for which it was originally designed.
- Remanufacturing
  - Remanufacturing involves a process of reducing a product into its constituent parts. It requires more extensive work, often complete disassembly of the product.

Recovery options in reverse logistics

- Recycling
  - Recycling is the process of collecting and disassembling used products, components and materials, and separating them into categories of like materials, such as plastic, glass etc., and then processing them into recycled materials.

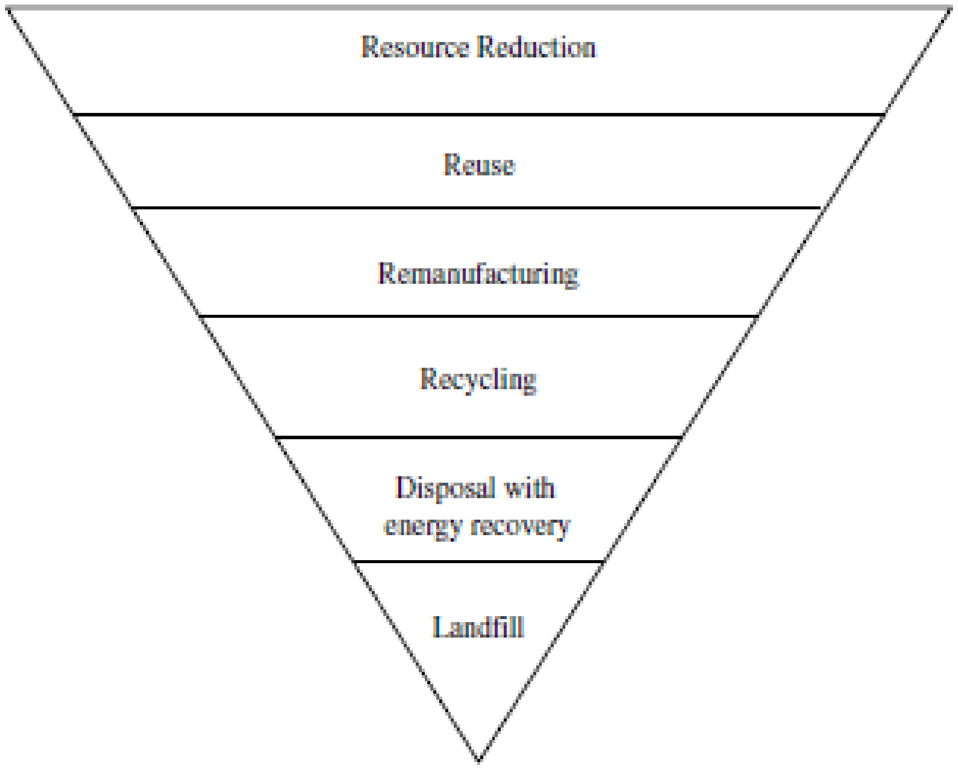


Figure 17.2 A recovery options hierarchy (Source: Carter & Ellram, 1998)[9]

A Reverse Logistics Network

A reverse logistics network may occur in either a **closed** or **open-loop** system.

- In **a closed-loop** reverse logistics system origins (sources) and destinations (sinks) coincide so that flows cycle in the system. Companies adopting this system collect their used products and either refurbish and resell or remanufacture them or they recycle them.

So who has the best supply chain?

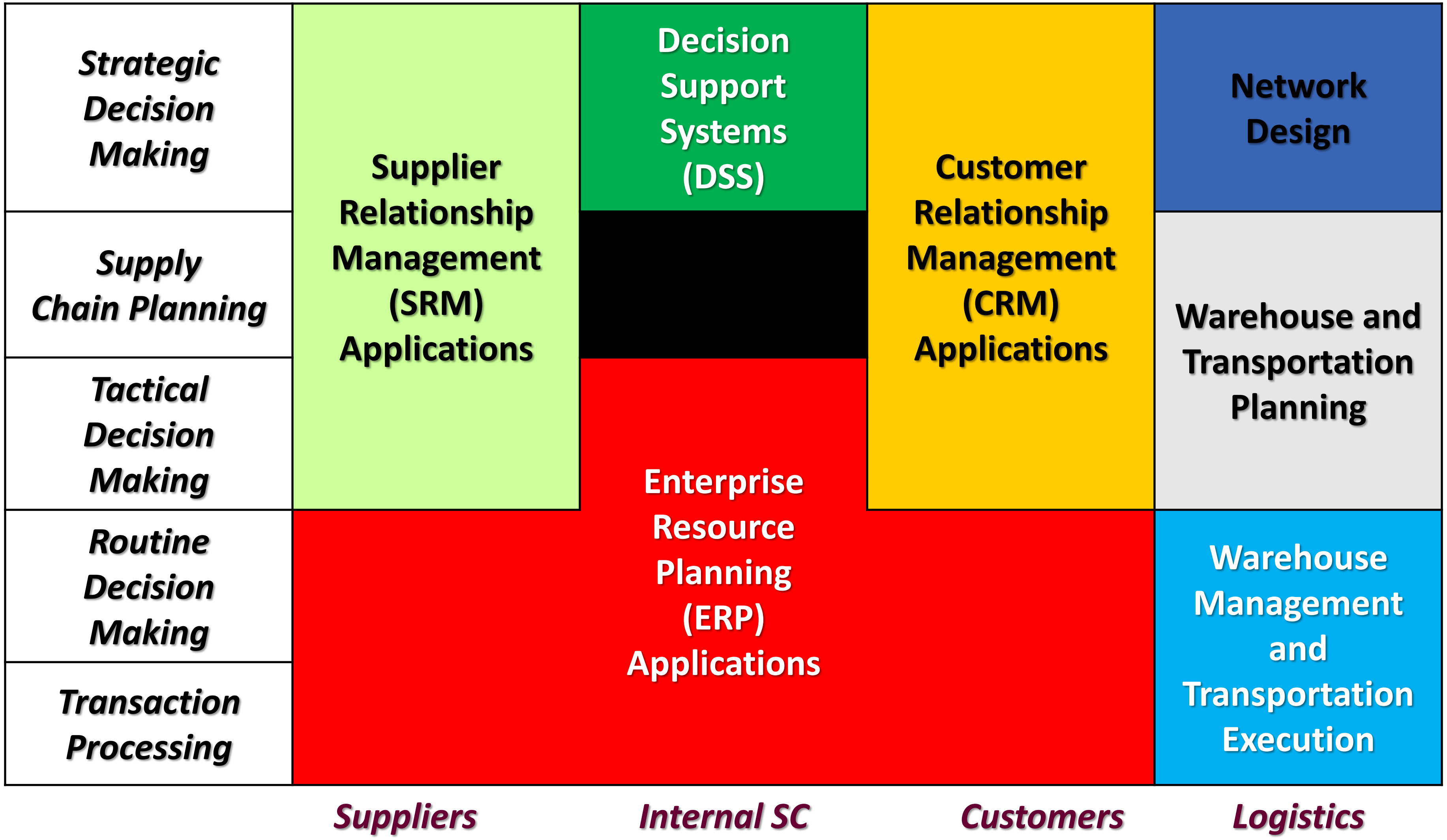
SO WHO HAS THE BEST SUPPLY CHAIN?

Gartner (www.gartner.com) each year produces a list of the top 25 supply chains, which is generated from an analysis that uses various input metrics. The top 25 for 2010 were:

1. Apple
2. Procter & Gamble
3. Cisco Systems
4. Wal-Mart Stores
5. Dell
6. PepsiCo
7. Samsung
8. IBM
9. Research in Motion
10. Amazon.com
11. McDonald's
12. Microsoft
13. The Coca-Cola Company
14. Johnson & Johnson
15. Hewlett-Packard
16. Nike
17. Colgate-Palmolive
18. Intel
19. Nokia
20. Tesco
21. Unilever
22. Lockheed Martin
23. Inditex*
24. Best Buy
25. Schlumberger

* Inditex is Zara's parent company.

A Map of SCM Systems



Important Elements of Supply Chain Management *(continued)*

Integration Elements:

- **Supply Chain Process Integration** - when supply chain participants work for common goals. Requires intra-firm functional integration, with efforts to change attitudes & adversarial relationships
- **Supply Chain Performance Measurement** - Crucial for firms to know if procedures are working as expected
- High level supply chain performance will occur when strategies at each firm fit well with overall supply chain strategies

Growth in international trade

- There has been considerable growth in recent decades in world trade; world exports grew from $62 billion in 1950 to a peak of $16,000 billion by 2008 before subsequently declining
- Facilitated by regional trade agreements
- Hence more freight is moving all around the world
  - Logistics systems are thus having to play an increasingly important role in the global economy

The evolution of the integrated supply chain

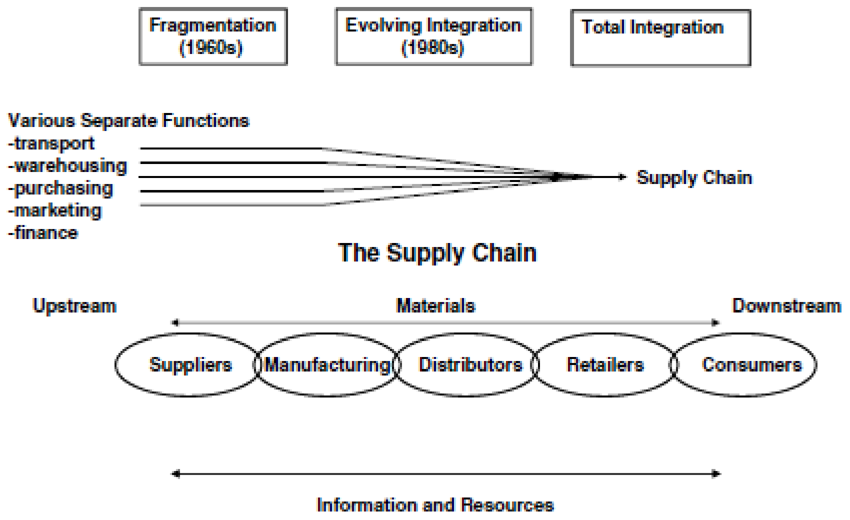


Figure 1.1 The evolution of the integrated supply chain

Measuring Logistics Performance

- The global logisitcs performance index (LPI) ranks 155 countries' logistics performance against six key dimensions:
  - Customs
  - Infrastructure
  - International shipments
  - Logistics competence
  - Tracking & tracing
  - Timeliness

Top 10 countries in the global LPI

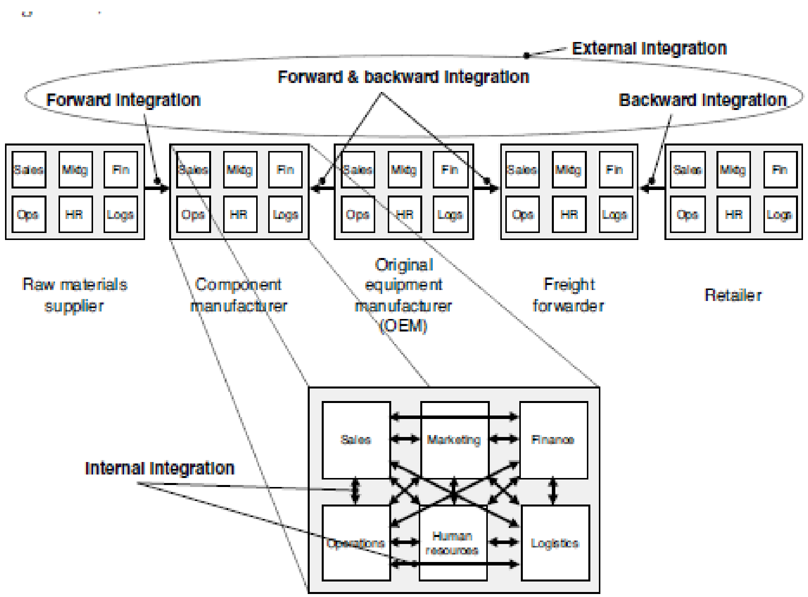
Table 2.1 Top 10 countries in the global logistics performance index (LPI)[7]

1	Germany
2	Singapore
3	Sweden
4	Netherlands
5	Luxembourg
6	Switzerland
7	Japan
8	United Kingdom
9	Belgium
10	Norway

Supply chain integration

- Integration embodies various communication channels and linkages within a supply network
- Integration should not be confused with collaboration
- Integration is the alignment and interlinking of business processes
- Collaboration is a relationship between supply chain partners developed over a period of time
- Integration is possible without collaboration
- Integration is an enabler of collaboration

Supply chain integration



Note: arrows do not represent material flows

Figure 3.3 Distinctions between the primary modes of integration (Source: Fawcett & Magnan 2002)[14]

Internal integration

- To integrate communications and information systems so as to optimise their effectiveness and efficiency
- Can be achieved by structuring the organisation and the design and / or implementation of information systems for improved communication and information sharing
  - Non-value adding activity is minimised
  - Costs are reduced
  - Leadtimes are reduced
  - Service quality is improved
  - Functional silos are reduced

External integration

- EDI is a key enabler of supply chain integration
  - It streamlines information sharing and processing
- Effective and efficient organisational design is a prerequisite
- Keiretsu:
  - Original equipment manufacturers work closely with their first tier suppliers to integrate manufacturing, logistics and information processes; which is passed upstream
    - This enables just-in-time line-side delivery at their assembly plants
    - A seamless lean supply chain is created
    - The supply chain is viewed as one extended operation

The journey from open market negotiations to collaboration

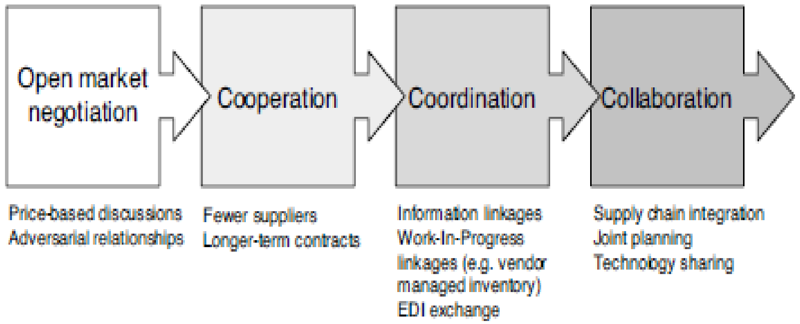


Figure 3.5 The journey from open market negotiations to collaboration (Source: Adapted from Spekman, Kamauff & Myhr 1998)[17]

Globalization

- <u>Benefits</u> (Macro-level view)
  - Lower prices
  - Wider availability of goods and services
  - Land and resource development
  - New employment opportunities
  - BRIC and VISTA countries

<u>Challenges</u> (Micro-level view)

- Increased level of complexity and competition
- Shorter product life cycles
- New forms of competition
- New business models