Materials Handling

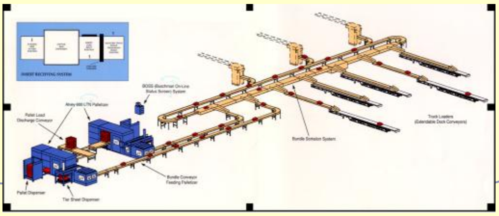
Chapter 9

Materials Handling

- Material handling is an activity that uses the right method to provide the right amount of the right material at the right place, at the right time, in the right sequence, in the right position and at the right cost

Materials Handling (Cont)

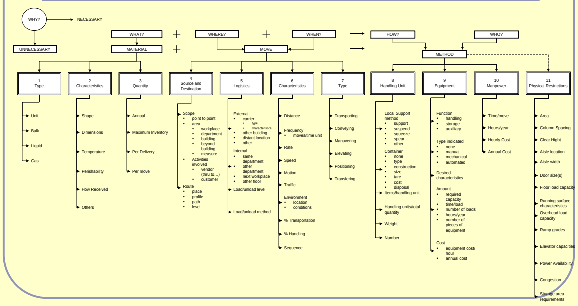
- Systems perspective
- 20-70% of product cost attributed to material handling



Materials Handling Equation

- Material Handling Equation (see Fig 11.3)
- MATERIAL + MOVE = METHOD

MH Equation



Materials Handling Principles

- Planning
- Systems
- Unit Load
- Standardization
- Space Utilization
- Automation
- Environmental
- Work
- Ergonomics
- Life Cycle

10 Principles of MH

Principle	Definition
Planning	A material handling plan is a prescribed course of action that is defined in advance of implementation, specifying the material, moves, and the method of handling
Standardization	Standardization is a way of achieving uniformity in the material handling methods, equipment, controls and software without sacrificing needed flexibility, modularity and throughput.
Work	The measure of work is material handling flow (volume, weight, or count per unit of time) multiplied by the distance moved.
Ergonomic	Ergonomics is the science that seeks to adapt work and working conditions to suit the abilities of the worker.

10 Principles of MH

Unit load	A unit load is one that can be stored or moved as a single entity at one time, regardless of the number of individual items that make up the load.
Space utilization	Effective and efficient use must be made of all available space.
System	A system is a collection of interdependent entities that interact and form a unified whole.
Automation	Automation is a technology for operating and controlling production and service activities through electro-mechanical devices, electronics, and computer-based systems with the result of linking multiple operations and creating a system that can be controlled by programmed instructions.
Environmental	The environmental principle in materials handling refers to conserving natural resources and minimizing the impact of materials handling activities on the environment.
Life cycle cost	Life cycle costs include all cash flows that occur between the time the first dollar is spent on the material handling equipment or method until its disposal or replacement.

Key Aspects of Planning Principle

- The plan should be developed as a consultation between the planner(s) and all who will use and benefit from the equipment to be employed.
- Success in planning large scale material handling projects generally requires a team approach involving management, engineering, computer and information systems, finance and operations.
- The materials handling plan should reflect the strategic objectives of the organization as well as the more immediate needs.
- The plan should document existing methods and problems, physical and economic constraints, and future requirements and goals.
- The plan should be flexible and robust, so that sudden changes in the process will not make the plan unusable.

Key Aspects of Standardization Principle

- The planner should select methods and equipment that can perform a variety of tasks under a variety of operating conditions and in anticipation of changing future requirements.
- Standardization applies to sizes of containers and other load forming components as well as operating procedures and equipment.
- Standardization, flexibility and modularity must not be incompatible.

Key Aspects of Work Principle

- Simplify processes by combining, shortening, or eliminating unnecessary moves to reduce work.
- Consider each pick-up and set-down or placing material in and out of storage, as distinct moves and components of distance moved.
- Design layouts and develop methods, and sequences, that simplify and reduce work.

Key Aspects of Ergonomic Principle

- Equipment should be selected that eliminates repetitive and strenuous manual labor and which effectively interacts with human operators and users.
- The ergonomics principle embraces both physical and mental tasks.
- Using ergonomics will improve production and reduce errors. The material handlings workplace and the equipment employed to assist in that work must be designed so they are safe for people

Key Aspects of Systems Principle

- Systems integration encompasses the entire supply chain including reverse logistics. The chain includes suppliers, manufacturers, distributors, and customers.
- At all stages of production and distribution minimize inventory levels as much as possible.
- Information flow and physical material flow should be integrated and treated as concurrent activities.
- Materials must be easily identified in order to control their movement throughout the supply chain.
- Meet customer requirements regarding quantity, quality, and on-time delivery, and fill orders accurately.

Key Aspects of Automation Principle

- Simplify pre-existing processes and methods before installing should be simplified or re-engineered before any efforts at installing mechanized or automated systems.
- Consider computerized material handling systems where appropriate for effective integration of material flow and information management.
- In order to automate handling, items must have features that accommodate mechanization.
- Treat all interface issues in the situation as critical to successful automation.

Key Aspects of Environmental Principle

- Design containers, pallets and other products used in materials handling so they are reusable or biodegradable.
- Systems design needs to include the by-products of materials handling.
- Hazardous material require special handling considerations.

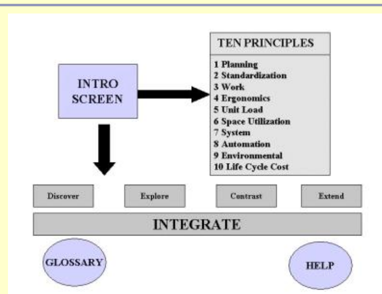
Key Aspects of Planning Principle

- The plan should be developed as a consultation between the planner(s) and all who will use and benefit from the equipment to be employed.
- Success in planning large scale material handling projects generally requires a team approach involving management, engineering, computer and information systems, finance and operations.
- The materials handling plan should reflect the strategic objectives of the organization as well as the more immediate needs.
- The plan should document existing methods and problems, physical and economic constraints, and future requirements and goals.
- The plan should be flexible and robust, so that sudden changes in the process will not make the plan unusable.

Key Aspects of Life Cycle Costs Principle

- Life cycle costs include capital investment; installation, setup, and equipment programming; training, system testing, and acceptance; operating, maintenance, and repair; and recycle, resale, and disposal.
- Plan for preventive, predictive, and periodic maintenance of equipment. Include the estimated cost of maintenance and spare parts in the economic analysis.
- Prepare a long range plan for equipment replacement.
- In addition to measurable cost, other factors of a strategic or competitive nature should be quantified when possible.

Multimedia CD



Unit Load

- Unit load - number of items or bulk material arranged so they can be picked up and delivered as one load
- Large or small?
- If large, cost/unit handled decreases
- But, depending upon
  - cost of unitizing, de-unitizing
  - space required for material handling
  - material handling carrier payload
  - work-in-process inventory costs
  - storage and return of empty pallets or containers used to hold the unit load
- smaller unit load may be desired

Unit Load (Cont)

- Seven steps to design a unit load
  - Unit load concept applicable?
  - Select the unit load type
  - Identify most remote source of load
  - Determine farthest practicable destination for load
  - Establish unit load size
  - Determine unit load configuration
  - Determine how to build unit load

Material Handling Device Types

- Conveyors
- Palletizers
- Pallet Lifting Devices
- Trucks
- Robots
- AGVs
- Jibs, Cranes and Hoists
- Warehouse MHSs
- CICMHE website
- CENTOR website

Conveyors

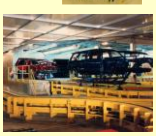
- Accumulation
- Belt
- Bucket
- Can
- Chain




Conveyors (Cont)

- Chute
- Gravity
- Pneumatic or vacuum
- Power and free
- Roller

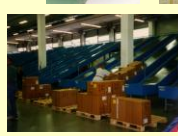




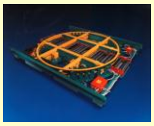

Conveyors (Cont)

- Screw
- Skid
- Slat
- Tow line
- Trolley
- Wheel



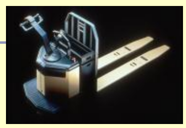



Palletizers

Pallet lifting devices

Trucks

- Hand truck
- Fork-lift truck
- Pallet truck
- Platform truck
- Counterbalanced truck
- Tractor-trailer truck
- AGV



Robots


- Point-to-point
- Contouring or continuous path
- Walkthrough or teach
- Lead through or teach pendant
- Hydraulic
- Servo-controlled

AGVs





Hoists, Cranes and Jibs



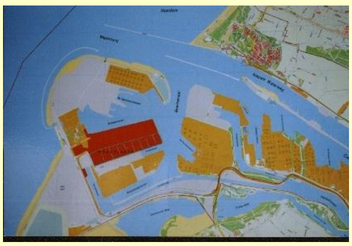
Warehouse MHSs

- Discussed in Chapter 10

MHSs in Action

- Europe Combined Terminals (ECT)
- ECT - one of largest in world and largest in Europe
- Goods shipped from and to Europe
- Built on reclaimed land in the North Sea
- Large and Small containers

MHSs in Action



MHSs in Action (Cont)

- Trucks wait to be off-loaded by straddle carrier
- Carrier takes container to holding area
- Shipped in approximately 2 days
- Mobile gantry cranes on tracks deposit containers in forward area

MHSs in Action

MHSs in Action (Cont)

- Mobile gantry cranes hold containers in top four corners and deposit on waiting AGVs
- Fleet of AGVs in forward area take containers to tower cranes
- Tower cranes deposit load on ship bed
- Procedure reversed for off-loading ship

MHSs in Action

MHSs in Action

MHSs in Action

AGVs

- Classification of MHS
  - Synchronous systems
  - Asynchronous systems
- Synchronous systems, e.g. conveyors, used in continuous processes or heavy traffic, discrete parts environments

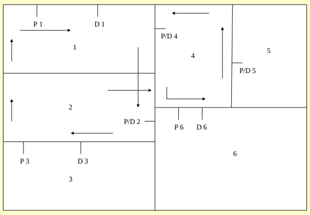
AGVs (Cont)

- Asynchronous systems, e.g., AGV, AS/RS, fork-lift trucks, monorails, cranes and hoists used in light traffic, discrete parts environments when material handling flexibility desired

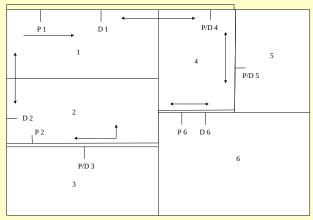
Design and Control Problems in AGVSs

- Material flow network
- Location of pick-up/drop-off (P/D) points
- Number and type of AGVs
- AGV Assignments to material transfer requests
- AGV routing and dispatching

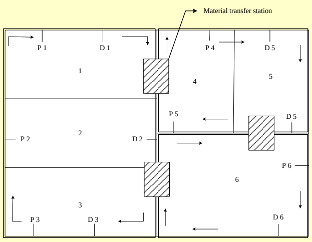
Unidirectional AGVs



Bi-directional AGVS



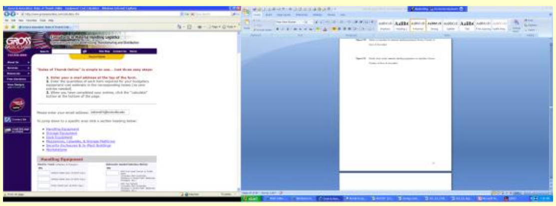
Unidirectional zoned AGVs



Design and Control Problems in AGVSs (Cont)

- Strategies for resolving
  - route conflicts, so AGV throughput rate is maximized
  - other costs (purchase, maintenance and operating costs of AGVs, computer control devices, and the material flow network, as well as inventory costs and production equipment idle costs incurred due to excessive material transfer and wait times), are minimized

Rule of Thumb Approach to MHS Design



Rule of Thumb Approach to MHS Design

Budgetary Warehouse/Distribution Equipment Cost Estimate
Produced with the Gross & Associates
"Rules of Thumb for Warehousing & Distribution Equipment Costs Online Calculator"
www.GrossAssociates.com

Qty	Equipment Description	unit price range		calculated price range	
		Low	High	Low	High
1	*Pallet Rack:* Standard Selective Pallet Rack	$ 50.00	$ 70.00	$ 50.00	$ 70.00
5	*Pallet Rack:* Double Deep Pallet Rack	$ 55.00	$ 80.00	$ 275.00	$ 400.00
5	*Pallet Rack:* Drive-In Pallet Rack (2 Deep)	$ 70.00	$ 100.0(	$ 350.00	$ 500.00
2	*Pallet Rack:* Drive-In Pallet Rack (3 Deep)	$ 60.00	$ 90.00	$ 120.00	$ 180.00
3	*Pallet Rack:* Drive-In Pallet Rack (4+ Deep)	$ 50.00	$ 80.00	$ 150.00	$ 240.00
10	*Shelf Bins (Heavy Duty Plastic):* 12" Deep: Small (3" 4" W x 4" 5" H)	$ 1.80	$ 2.25	$ 18.00	$ 22.50
12	*Shelf Bins (Heavy Duty Plastic):* 12" Deep: Large (6" 8" W x 4" 5" H)	$ 3.00	$ 4.50	$ 36.00	$ 54.00
8	*Shelf Bins (Heavy Duty Plastic):* 18" Deep: Small (4" 6" W x 4" 5" W)	$ 2.25	$ 3.50	$ 18.00	$ 28.00
5	*Shelf Bins (Heavy Duty Plastic):* 24" Deep: Small (4" 6" W x 4" 5" H)	$ 4.00	$ 6.25	$ 20.00	$ 31.25

MHD Selection and Assignment Model

- Minimizes operating and annualized investment costs of MHD
- Variables and parameters
  - i part type index, i=1,2,...,p
  - j machine type index, j=1,2,...,m
  - l MHD type index, l=1,2,...,n
  - L_i set of MHDs that can transport part i
  - H length of planning period
  - D_i # of units of part type i to be produced

MHD Selection and Assignment Model (Cont)

- K_{ij} set of machines *to* which part type i can be sent from machine j for next process
- M_{ij} set of machines *from* which part type i can be sent to machine j for next process
- A_i set of machine types required for the first operation on part type i
- B_i set of machine types required for last operation on part type i

MHD Selection and Assignment Model (Cont)

- V_l purchase cost of MHD H_l
- T_{ijkl} time required to move one unit of part type i from machine type j to k using MHD l
- C_{ijkl} unit transportation cost to move part type i from machine j to k using MHD l
- X_{ijkl} number of units of part type i to be transported from machine j to k using MHD l
- Y_l number of units of MHD type l selected

MHD Selection and Assignment Model (Cont)

$$Min \sum_{l=1}^{n} V_l Y_l + \sum_{i=1}^{p} \sum_{j=1}^{m} \sum_{k \in K_{ij}} \sum_{l \in L_i} C_{ijkl} X_{ijkl}$$

Subject to

$$\sum_{j \in A_i} \sum_{k \in K_{ij}} \sum_{l \in L_i} X_{ijkl} = D_i i = 1,2,\ldots, p$$

MHD Selection and Assignment Model (Cont)

$$\sum_{k \in M_{ij}} \sum_{l \in L_i} X_{ijkl} - \sum_{k \in K_{ij}} \sum_{l \in L_i} X_{ijkl} = 0 \quad i = 1,2,\ldots, p;\ j : j \notin A_i \bigcup B_i$$

$$\sum_{j \in B_i} \sum_{k \in M_{ij}} \sum_{l \in L_i} X_{ijkl} = D_i \quad i = 1,2,\ldots, p$$

$$\sum_{i=1}^{p} \sum_{j=1}^{m} \sum_{k \in K_{ij}} X_{ijkl} T_{ijkl} \leq HY_l \quad l = 1,2,\ldots,n$$

$$X_{ijkl} \geq 0,\ Y_l \geq 0 \text{ and integer} an \quad i = 1,2,\ldots, p;\ j = 1,2,\ldots,m;\ k,l = 1,2,\ldots,n$$

Example for MHS Selection and Assignment

- Small manufacturing system
- Processes two high volume parts P_1 and P_2- 50 and 60 units, respectively
- Part P_1 processed first on machine M_1, and on machines M_2 or M_4 for second step and to machine M_3 for final step

Example for MHS Selection and Assignment (Cont)

- Of the 60 units of part P_2, 30 are processed first on machine M_1 and then on machine M_2.
- The remaining 30 units of part P_2 are processed first on machine M_3 and then sent to machine M_2 for final processing

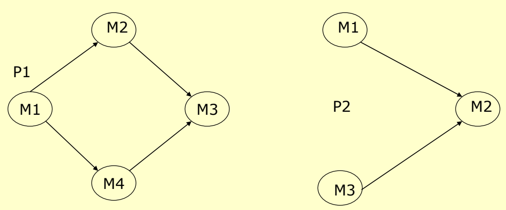
Example for MHS Selection and Assignment (Cont)

- Two candidate MHDs - H_1 and H_2 with purchase costs of $100,000 and $140,000 available
- Unit cost for transporting P_1 and P_2 on each of the MHDs as well as transportation times given

Example for MHS Selection and Assignment (Cont)

- Assume there are 7150 seconds in the planning period
- Each handling device is expected to make empty trips 30% of the time
- Determine the required MHDs and assign departmental moves to them

Example for MHS Selection and Assignment (Cont)



	Fm	To	M1	M2	M3	M4
P1	M1	H1		7(10)		8(5)
		H2		5(8)		2(2)
P1	M2	H1			8(6)	
		H2			4(5)	
P1	M4	H1			8(8)	
		H2			4(5)	
P2	M1	H1		2(4)		
		H2		1(2)		
P2	M3	H1		20(6)		
		H2		12(2)		

MILP Model for Example 1

```
MIN 100000 Y1 + 140000 Y2 + 7 X1121 + 5 X1122 + 8 X1141 + 2
  X1142 + 8 X1231 + 4 X1232 + 2 X2121 + X2122 + 20 X2321 + 12
  X2322 + 8 X1431 + 4 X1432
 SUBJECT TO
2)   X1121 + X1122 + X1141 + X1142 =    50
3)   X2121 + X2122 =    30
4)   X2321 + X2322 =    30
5)   X1121 + X1122 - X1231 - X1232 =    0
6)   X1141 + X1142 - X1431 - X1432 =    0
7)   X1231 + X1232 + X1431 + X1432 =    50
8) - 5005 Y1 + 10 X1121 + 5 X1141 + 6 X1231 + 4 X2121 + 6
  X2321 + 8 X1431 <=   0
9) - 5005 Y2 + 8 X1122 + 2 X1142 + 5 X1232 + 2 X2122 + 2
  X2322 + 5 X1432 <=   0
 END  INTE     2
```

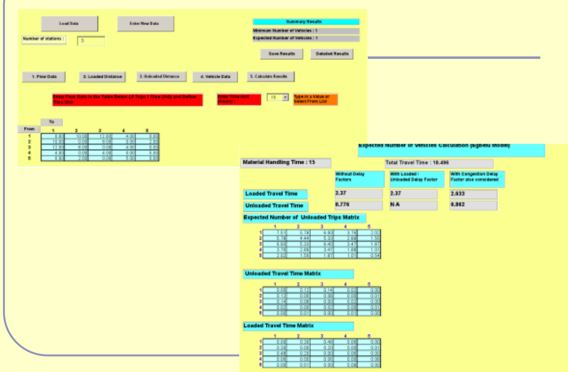
Solution for Example 1

```
OBJECTIVE FUNCTION VALUE
        1)       101410.0
Y1          1.000000      X1121         50.000000      X1231
   50.000000
X2121      30.000000 X2321          30.000000
```

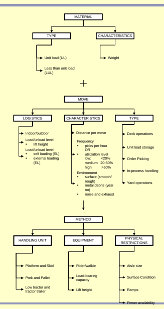
Queuing Model for MHS Design

- Example 2: A bottled water producer in New England has a large warehouse adjoining the bottling facility. Pallets of bottled water cases have to be delivered from the palletizer to the warehouse. The company has decided to use fork lift trucks for delivery of the pallets to the warehouse. These can be leased from a manufacturer. It has been determined that it takes an average of 15 minutes for a fork lift truck to travel from the palletizer to the warehouse, unload the pallet and return to the palletizer in the bottling facility. An operator is required to assist in the loading operation and this takes twelve minutes per pallet on average. Two or three such operators are available. Given that the inter-arrival and operator service times follow an exponential distribution, operator and fork lift leasing hourly costs are $20 and $50, respectively and that the company wants to lease 5 trucks, determine whether 2 or 3 operators should be assigned in order to minimize the operator *and* fork lift truck idle time.

AGV-DST



Expert Systems for Truck Selection



Expert Systems for Truck Selection

Truck Type	Material					Move								Method					
	Type		Weight			L/UL Method		L/UL Level			Utilization			Operation		Physical Restrictions			
	UL	LUL	<5k	5-8k	>8k	SL	EL	GL	<30'	30-45'	<20%	20-50%	>50%	Rider	Walkie	Ramp	Rough	Smooth	Noise
Walkie Stackers	X		X			X			X				X		X	X		X	
Tow Tractors	X				X	X		X			X	X		X					

Models for Conveyor Performance Analysis

- There are *m* stations which load or unload *n* carriers
- Amount of material loaded on the j^{th} carrier as it passes station *i* is f_{ij}
- If material unloaded, assign a negative value to f_{ij}
- Load/unload cycle is a period of length *p*

Models for Conveyor Performance Analysis (Cont)

- Construct a set $F_i = \{f_{i1}, f_{i2}, ..., f_{ip}\}$ including load/unload activities carried out in p successive carriers
- For e.g., if add one load to one carrier at the first station, unload two from the next and let the third one go by without loading or unloading and repeat, cycle has a period of length 3
- $F_1 = \{1, -2, 0\}$

Models for Conveyor Performance Analysis (Cont)

- p need not be equal to n.
- In a cycle, total material loaded must be equal to total unloaded

$$\sum_{i=1}^{m} \left(f_{i1} + f_{i2} + ... + f_{ip} \right) = 0$$

Models for Conveyor Performance Analysis (Cont)

- One round completed when all m carriers have gone around the conveyor once
- So, n/p load and unload cycles in the first round
- If carrier j is in some position of the load/unload sequence (with respect to station i) during one round, it need not be in same position in subsequent rounds

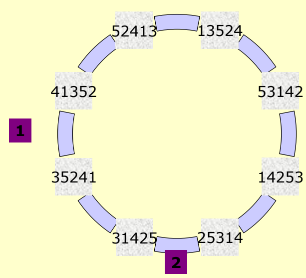
Models for Conveyor Performance Analysis (Cont)

- It can be shown that if n mod p is not equal to 0, load picked up or dropped off will change from one round to the next, for the same carrier at the same station
- Let P_{ijk} be the load/unload sequence position of a carrier j, with respect to station i in round k

Models for Conveyor Performance Analysis (Cont)

- Given P_{ij1}, P_{ijk} can be determined using the following formula, for k=2, 3, ..., p
- $P_{ijk} = [P_{ijk-1} + n \text{ mod } p] \text{ mod } p$
- After p rounds, the position sequence repeats itself
- If P_{ijk}=0, set $Pijk=p$

Models for Conveyor Performance Analysis-Example



Models for Conveyor Performance Analysis-Example

- Load/unload cycle length has a period 5
- F_1={2, 0, 2, 0, 3}; F_2={-2, 0, 0, -1, -4}
- Determine the conveyor capacity

Models for Conveyor Performance Analysis-Example

- Do Example 3

Models for Conveyor Performance Analysis-Example

und No.	Position No.	Loads		Cumulative Loads		Adj. Cumulative Loads	
		Station 1	Station 2	Station 1	Station 2	Station 1	Station 2
1	1	2	-2	2	0	4	2
2	4	0	-1	0	-1	2	1
3	2	0	0	-1	-1	1	1
4	5	3	-4	2	-2	4	0
5	3	2	0	0	0	2	2
6	1	2	-2	2	0	4	2
7	4	0	-1	0	-1	2	1
8	2	0	0	-1	-1	1	1
9	5	3	-4	2	-2	4	0
10	3	2	0	0	0	2	2

Models for Conveyor Performance Analysis (Cont)

- Change conveyor capacity requirement in one of three ways
  - Change number of carriers n. P_{ijk} will change resulting in different cumulative loads and hence, carrier capacity
  - Change load/unload sequence of one or more stations
  - Change the location of one or more stations

Queuing Network Model for Analysis of MHS Systems

Mean Value Analysis Algorithm

Step 1: The first step is to estimate an initial value of L_{ij}. The best method is to evenly distribute a part over all the stations it visits.

Step 2: Determine the throughput time W_{ij} using the equation

$$W_{ij} = \frac{1}{\mu_i^j} + \left(\frac{N^j - 1}{N^j}\right)\left(\frac{L_{ij}}{\mu_i^j}\right) + \sum_{r \neq j} \frac{L_{ir}}{\mu_i^r}$$

Step 3: Determine the production rate X_j using the equation

$$X_j = N^j / [\sum_{i=1,..m} (v_{ij} W_{ij})]$$

Step 4: Determine the queue length L_{ij} using the equation $L_{ij} = X_j (v_{ij} W_{ij})$.

Step 5: Compare the L_{ij} value calculated in step 4 with the previous value. If the new value is within a desired range of the previous value, stop. If not, go to step 2.

Models for Conveyor Performance Analysis-Example

- Do Example 5 - MVA