UNIT-14

Warehouse Operations & Systems

Learning Outcomes
By the end of this unit the learner will be able to:
✓ Understand centralised and decentralised warehouse operations ✓ Discuss the implementation of warehouse storage systems ✓ Explain the pros and cons of various types of racking and conveyor systems

Unit 14

Warehouse Operations & Systems

Warehouse Operations - Centralised and Decentralised

Where a business uses multiple warehouses, its warehouse operations can be either centralised or decentralised. With decentralised warehousing, this is where every warehouse operated by the business is an independent entity. Or to put it another way, every warehouse has its own safety stock and optimises/managers its own inventory as a completely separate and individual operation. Decentralised warehouses are not dependent on one another to function.

Decentralised warehousing is a preferable choice when consumption centres are located far away from one another. The primary advantage of decentralised warehousing is that it helps avoid the accumulation of surplus materials and reduces the risks associated with interdependence between warehouses and logistics facilities.

However, decentralised warehousing can also be comparatively expensive, due to the increased requirement for manpower at the warehouses established and elevated information handling requirements.

With centralised warehousing, storage of safety stock, order processing and general primary inventory management operations are handled at a central warehouse. Where additional warehouses are used by the business, they are set up primarily as storage facilities, rather than independent or self-contained entities in their own right.

Centralised warehousing can also be advantageous, in that total inventory costs are reduced, and less overall safety stock is required. The central warehouse must manage the record keeping and general administrative/management operations of its branch warehouses, but the costs of doing so may be augmented by these reduced inventory costs.

The central warehouse makes all decisions regarding when new stocks should be ordered and how much, based on the requirements of each branch warehouse accordingly. Issues occur when decisions are made using erroneous, incomplete or outdated information, which can result in too little stock being ordered, or the procurement of excessive safety stock for any given branch warehouse.

Storage systems

Warehouses are used to store, move and process an extensive variety of items and materials. All of which have their own unique characteristics, in terms of size, weight, shape, fragility, value and special requirements. One of the biggest advantages of using standardised storage and movement systems (such as pallets) is that they are compatible with most modern handling equipment and warehouse storage systems, regardless of the specifics of the items being stored. Warehouses are often required to have multiple storage systems within the same facility, in order to accommodate different types of items with different requirements.

Important considerations when deciding on an appropriate storage system include:

- The nature and characteristics of the goods and unit loads held
- Ensuring efficient utilization of the available space
- Quick and easy access to stocks carried
- Compatibility with information system requirements
- Maintenance of stock condition and integrity
- Warehouse operative health and safety
- The costs of the system

Evaluating storage system costs is also important, which means thinking beyond the basic equipment needed to set up the storage system. Additional costs that must be brought into consideration include:

- Fire protection and general safety/security
- Manpower needed to operate the warehouse
- Information management systems
- Availability of space/land
- General building services

One way of classifying storage systems could be:

- Bulk storage for solids, such as silos, bunkers and stockpiles
- Loose item storage, ex casting and fabrications held loose on the floor
- Pallet storage systems
- Small item storage for individual items or small unit loads
- Non-standard unit loads such as long loads

One of the most important elements of an effective stock management strategy is the appropriate location of items within the facility. The idea being that the amount of movement required to get materials/items from where they are to where they need to be is minimised where possible. This will have a direct impact on the speed and efficiency of all storage, picking and general materials handling processes within the warehouse.

Fixed and random stock location

There are advantages to both fixed and random stock storage practices.

When a warehouse uses a fixed location system, this means that every product/item has its own designated storage space, which must not be used for any other item at any time. Ensuring all items are stored in specified and predetermined locations at all times can be beneficial, but this nonetheless means ensuring that the facility has the size and capacity to accommodate the maximum stock of *every* product line.

Random location (as the name suggests) allows for empty space around the warehouse to be used to store any products or materials, as and when required. This allows for the total size and capacity of the facility to be reduced, as there is technically very little chance of every product being in stock at maximum stock levels at the same time. Instead, it's a case of calculating the average overall stock level for all product lines to determine how much space is required, allowing an additional 10% or so for fluctuations.

It's not uncommon for warehouses to use a combination of fixed and random stock locations.

Palletised storage systems

The use of pallets has become a universal standard for most warehouses worldwide.

Block stacking

Block stacking refers to the process of placing loaded pallets directly on to the floor, stacked on top of one another to a predetermined maximum safe height. This can be an affordable storage system as no additional storage equipment (such as racking) is necessary. In order to function, the warehouse simply needs the required equipment to move and lift the pallets.

Rapid throughput and flexibility of layout are additional benefits to the block stacking model. However, it is not an appropriate system where FIFO (first in, first out) movement is an important priority for the business.

Drive-in and drive-through racking

Drive-in and drive-through racking is technically similar storage system to block stacking, though with the addition of racking to support the pallets. The pallets are still stored on top of one another, but the system uses vertical support frames where pallet loads are either irregularly shaped or not strong enough to be stacked directly one on top of the next. Forklift trucks are used to place the pallets on the rails and retrieve them when required.

A well-designed drive-in and drive-through racking system can be exceptionally efficient, in terms of making the best possible use of all available floor space. For example, approximately 75% more pallets can be stored in a drive-in/drive through system than in a selective rack system.

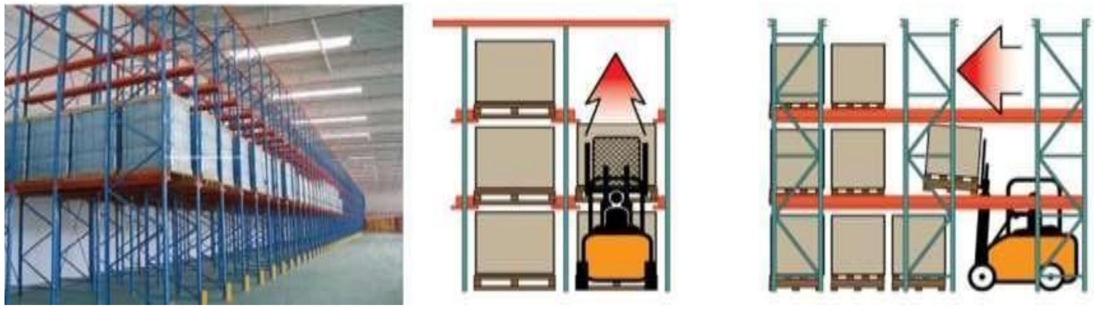

Figure: 14.1

Push back Racking

Another popular palletised storage system, push back racking provides a high-density solution to make good use of both vertical and horizontal space. Systems can be built as high as the lifting vehicles accessing the pallets allow, typically storing pallets on rails up to four pallets deep. There should be no mix of product lines in any one lane, but there can be between the lanes in any row.

Figure 14.2

Adjustable Pallet Raking (APR)

This is perhaps the most commonly used storage system in the vast majority of warehouses worldwide. Adjustable pallet racking (or APR) is a system that provides the warehouse operatives with free access to every pallet at any time. Pallets are stored back to back with aisles in between, featuring racks that can be built as high as the lifting vehicles allow. As the pallets are never stored more than one deep, all goods and items stored can be accessed quickly and efficiently.

The image below demonstrates how adjustable pallet racking is used in a typical warehousing environment. While APR can be excellent for providing quick and easy access to stocks, it does not make efficient use of all available space.

Figure 14.3

Double deep Racking

Double-deep racking to some extent combines the principles (and some of the benefits) of adjustable pallet racking with those of block stacking/push back racking. Space utilisation is significantly increased, though at the cost of totally free access to stocks held.

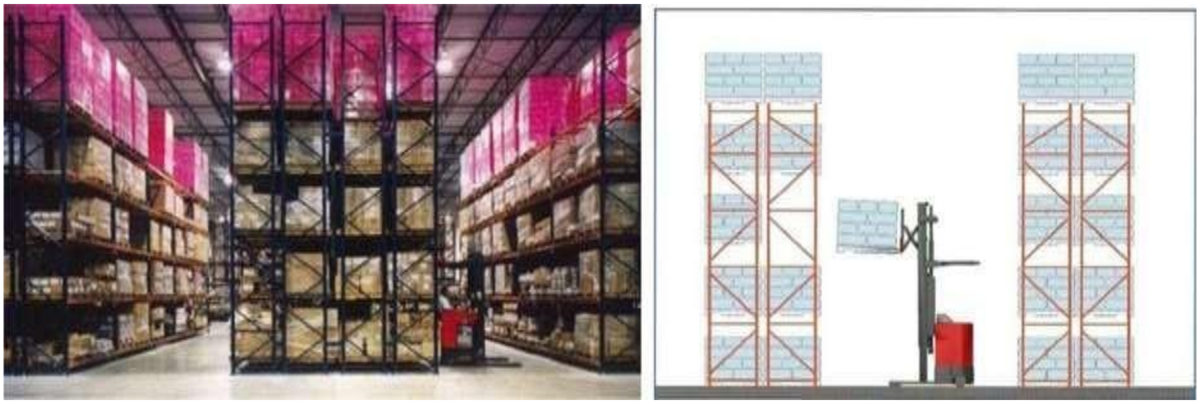

Figure 14.4

Powered Mobile racking

An advanced powered mobile racking system can make exceptionally efficient use of all available floor space. This is essentially a single-deep APR system, though in this instance the storage units are mounted on electronic movement systems. This enables the racks to move horizontally as required, in order to enable lifting equipment to access pallets across the whole system. Powered mobile racking can increase floor space utilization efficiency to as much as 95%, but it is nonetheless a comparatively expensive system to set up in the first place. In addition, it has a tendency to be somewhat slow to operate, as extensive movement of the racks may be needed to access each individual item held, one after the next.

Figure 14.5

Pallet live storage

A pallet live storage system usually uses gravity-powered conveyors, which automatically move pallets from the loading point at the top to the retrieval point at the bottom. Pallets can only be accessed at the out feed end, which makes it a great system for ensuring FIFO (first in, first out) rules are followed at all times.

Pallet live storage systems are suitable for very fast-moving product lines. They can provide effective order picking regimes, which automatically refill empty locations, and also provide physical separation between picking and replenishment operations.

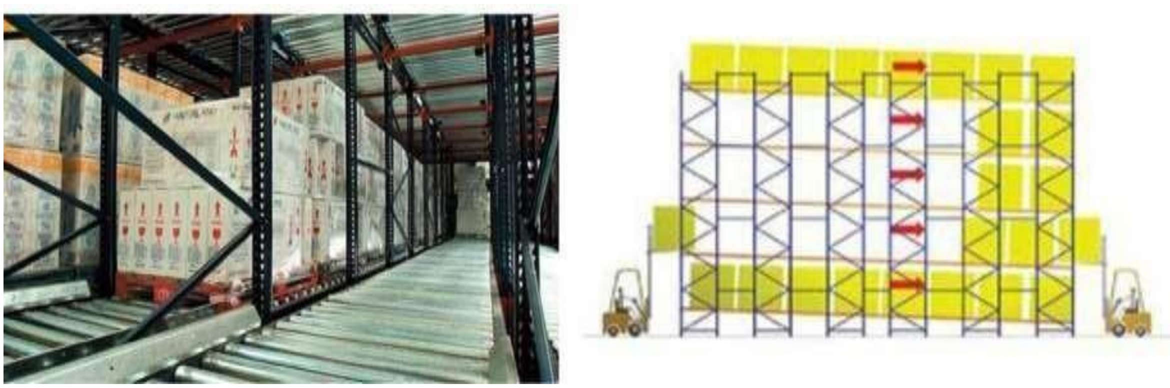

Figure 14.6

Small item storage systems

Along with storage systems for pallets, there are also various different ways of storing smaller items and materials within a warehouse. In most instances, warehouses use a multitude of small item storage systems within the same facility. Many of which may be built directly into their primary racking systems, or designed to work seamlessly alongside them.

Just a few examples of typical small item storage systems include:

- Shelving
- Tote bins
- Drawer units
- Dynamic systems –mobile and live storage
- Mechanised systems- carousels and mini loads

Types of conveyors

1. **Fixed Path Conveying**
   Fixed path conveyers are used to move items and materials between fixed locations in factories, warehouses, processing facilities and so on. They can be used to provide a continuous work surface for an assembly line, change elevations, store packages, accumulate goods and so on.

   Conveying systems Planning Criteria:

   - Product size and weight (or container characteristics if used)
   - Distance
   - Control requirements
   - Flow Rates
   - Obstructions and facility limitations
   - Human factors, including noise
   - Environment

2. **Gravity Conveyors**
   As the name suggests, this is a type of conveyer that is powered by gravity, therefore needs no supply of electricity to operate. They are also typically the cheapest and easiest conveyor systems to design and install, often used to move materials and items short distances only.
   Three common types are chutes, skate wheels, and rollers. They are often used in conjunction with powered systems:

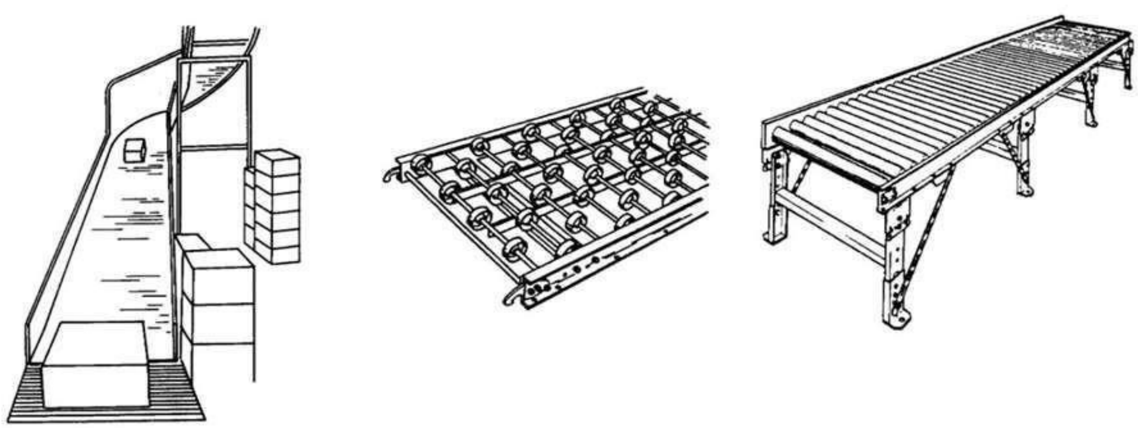

Figure 14.7

Above: in order, chute, skate wheels and roller gravity conveyers

Advantages of Gravity Conveyors

- Ideal for changing elevations
- Comparatively cheap and easy to set up
- Minimal noise output

- Easy to use (no specialist training required)
- Low profile and low maintenance
- Minimal ongoing operational costs
- Can be designed in any configuration required

Disadvantages of Gravity Conveyors

- Less direct control over the items being moved
- Unsuitable for more fragile items and materials
- Singulation and non-contact difficult
- Tend to increase the work in progress
- High pitch requirements
- May require manual assistance
- Horizontal powered conveyors

These are used to move material over moderate to long distances.

Live Roller

Live rollers are powered material movement systems that can be used to handle relatively heavy and irregularly shaped items. A well-designed live roller system can be extremely efficient and easy to work with, though it can also be disadvantageous by way of the following:

- Product slippage on rollers requires frequent tracking update and diverter timing
- Products cannot negotiate inclines over 7 degrees without manual assistance
- Elevated initial setup costs
- Power surges when accumulating on driving rollers; disrupting product spacing

3. **Live Roller Accumulation Conveyors.**
   Live roller accumulation conveyors are used to create temporary buffers for access items and materials being moved.

4. **Slider Bed/Roller Bed Conveyors**
   This is a relatively simple and inexpensive system that uses a steel support bed and a moving belt supported by rollers. Such systems need more power to operate than a live roller, typically being used to handle heavy loads and often at higher speeds. They can also accommodate declines and inclines up to a maximum of 30°.

5. **Roller Curves and belt Turn Conveyors**
   Roller curves are more commonly used than belt curves, and are typically more cost effective to install and operate. However, both roller curves and belt turn conveyors are used to change material flow direction in a conveyor system.

6. **Sortation Conveyors**
   Sortation conveyors are used to identify packages, present packages to sortation equipment,

or sort packages to multiple locations.

7. **Powered Overhead Conveyors**
   Ideal for transporting materials and items around the warehouse where floor space is limited or congested.

8. **Vertical Conveyors**
   Used in facilities that make optimum use of vertical space to raise or lower materials and items between different levels as required.

Figure 14.8

Automated Storage and Retrieval System

A relatively new introduction to warehousing, automated storage and retrieval systems (ASRS or AS/RS) use specially-designed hardware and software to automatically store and retrieve items and materials from predetermined locations. Due to the costs and complexity of such systems, they are typically only used where very high volumes of goods are moved on a continuous basis. Automated storage and retrieval systems can also significantly boost picking accuracy, reduce complications associated with handling nonstandard loads and generally improve the safety and efficiency of a warehousing facility.

The concept of automated storage and retrieval has been around for more than 50 years, though has become significantly more advanced in the 21st century. In some automated warehousing environments, there is now little to no requirement whatsoever for traditional manpower. Operations that would previously have necessitated a workforce of dozens (or even hundreds) of workers can now be overseen by just a handful of skilled operatives. Of course, this also presents an inescapable ethical debate - the extent to which it is right to eliminate jobs in favour of automation.
Automated storage and retrieval systems can be enormously beneficial from a business perspective, but at the same time have already cost thousands of traditional warehouse operatives their jobs.

Advantages

Some of the biggest advantages of installing and using an automated storage and retrieval system include:

- An advanced automated storage and retrieval system can make highly-efficient use of all available space, with particularly heavy emphasis on vertical storage to minimize the amount of floor space required.
- Significant reductions in workforce requirements and subsequent labour costs for the business, as most key operations are automated.
- Improvements to workplace health and safety, eliminating the requirement for warehouse operatives to physically handle/move items and materials.
- All aspects of the automated storage and retrieval system can be linked with powerful inventory management software, ensuring accurate records are kept and the risk of human error is significantly reduced.
- The capacity for automated software to track and analyse important data, providing business owners and warehouse operatives with important insights as to how operations could be made more efficient or cost effective.

Automatic Storage and Retrieval Systems (AS/RS) for Unit Loads

The basic components of an AS/RS system are:

- Storage medium, e.g. pallet racking, or shelving for small-item tote bins
- Storage and retrieval machines that operate in the storage medium
- In-feed and out-feed systems, e.g. forklift trucks, conveyors, AGVs (Automatic Guided Vehicles)
- Controlling computer hardware and software

Specially-designed computer hardware and software suites monitor the physical movements of the system, while at the same time keeping detailed records of everything that takes place.

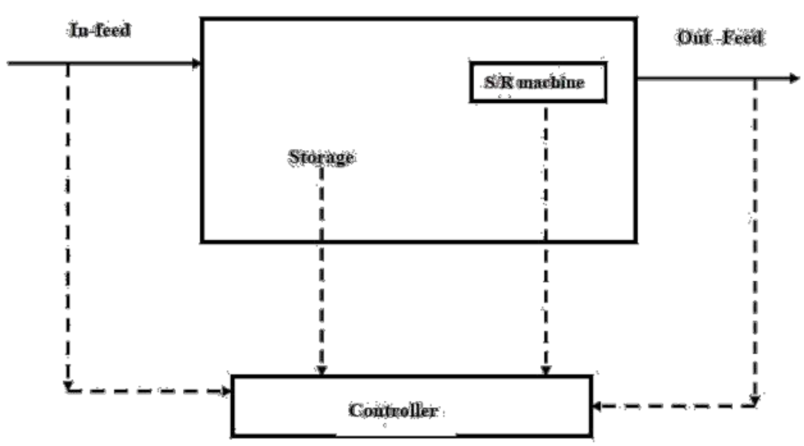

Figure 14.9

Design of Automatic Storage and Retrieval Systems (AS/RS)

Automated storage and retrieval systems are designed from scratch to meet the exact requirements of the business. In order to make the best possible use of all available space, it is not uncommon for storage units in an automated warehousing environment to exceed 45 metres in height. Spaces between the racks can also be kept to absolute minimums, as there is no requirement for human operatives to move between the racks to store, retrieve or examine the items stored.

Stacker cranes controlled by the central computer system are used to store and retrieve items from the racking. The number of cranes required will be determined by the size, capacity and general movement requirements of the warehouse. In high-volume facilities, multiple stacker cranes are used to boost speed and efficiency.

Though complex, the overall purpose of an automatic storage and retrieval system is relatively simple. That being, to get incoming goods positioned in their appropriate storage locations as quickly as possible, while simplifying and accelerating picking processes for outgoing shipments. The vast majority of which can be achieved with little to no operator supervision or intervention whatsoever. A series of cranes, conveyors and automatic vehicles handle all material movement requirements from start to finish, while at the same time automating the administrative aspects of warehouse management.

However, it is important to note that the vast majority of 'automated warehouses' in operation today are only semi-automated. Partial automation has become much more widespread over recent years, wherein certain aspects of storage and picking processes have indeed been automated. However, human involvement remains of vital importance in most warehousing facilities. To achieve 'true' automation is to automate all (or the vast majority of) major warehousing operations, which simply isn't the case in most semi-automated warehousing environments.

The Principles and Performance Measures of Material Handling Systems

Measuring the performance and efficiency of a material handling system can be difficult, as there are various different metrics that can be measured. Examples of which include:

1. The entire manufacturing system (e.g. job throughput),
2. The material handling system independently (e.g. vehicle travel distance).

Though often interpreted as the same, the efficiency and effectiveness of a material handling system are in fact quite different. A material handling system's effectiveness refers to its capacity to achieve the required result, while efficiency refers to its cost-effectiveness and general performance. Just as it is possible to have an efficient system that is ineffective, an effective system isn't necessarily efficient.

Vehicle travel: Distance (or travel time)

When used as a factor for measuring the performance of a material handling system, vehicle travel refers to the actual path distances travelled by both loaded and empty vehicles. The flow of materials using such vehicles may be:

1. Departmental (within departments)
2. Intra-departmental (between departments)

Material flow within departments is usually not modelled in material handling system analysis.

The measurement of vehicle travel may include loaded vehicle travel, empty vehicle travel, or both. Vehicle travel distance is easily calculated when the flow volumes (trips required per unit time) and distances between stations are known.

Vehicle travel time directly corresponds to vehicle distance when:

1. The vehicle speed is constant or may be assumed to be constant,
2. The acceleration and deceleration effects are negligible
3. There are no delays due to blocking, queues or other congestion effects.

Another vehicle travel distance measure is the average loaded or empty vehicle travel. This measure is defined as the average time to complete a transportation task. A measure is also taking vehicle travel using the ratio (RLE) of empty versus loaded vehicle travel.

RLE = TL/ TE

Where TL total loaded travel time,

TE total empty travel time.

Vehicle travel proportions

A vehicle may be in one of three states at any given time:

1. Travelling loaded,
2. Travelling empty
3. Idle.

Idle time spent in the parking area is used as a performance measure. Then, travel time percentages may be calculated as the fraction of time that a device is travelling loaded, travelling empty, and waiting in an idle state. That is,

T = TL + TE + TI,

Where

TI total idle time,

T total time,

TL as above (total loaded travel time),

TE as above (total empty travel time).

Vehicle travel: response time

Response time for a pick-up call is also considered as a performance measure. The define response time for a pick-up call is the time from when the pick-up request is made until the vehicle (starting from an idle and empty condition) arrives at the pick-up location. This measure differs from the total empty vehicle transportation time in that it consists of only empty vehicle travel when the vehicle starts from an idle position and does not include empty vehicle travel from a drop-off station to a pick-up station.

Handling time per job

The handling time per job is comprised of the time directly associated with material handling.

This time includes:

1. The time the job spends in queues waiting for the material handling vehicle,
2. The total travel time,
3. The total loading and unloading times
4. Total vehicle blocking times.

The total handling time per job includes the time from when a job enters the system until it leaves the system.

Vehicle utilisation

Vehicle utilisation may be used to determine the vehicle fleet size requirements for a system.

Vehicle utilisation may be based on:

1. The total vehicle mission time (including loaded and/or empty vehicle travel),
2. The loaded vehicle time
3. The average of the time-averaged loads carried by all vehicles in the system.

(Note: when the vehicles are able to carry multiple loads, the utilisation value may be larger than one.)

Number of loads completed

The number of loads completed is defined as the number of loads (or deliveries) completed over a period of time by all of the material handling vehicles. The number of loads completed is considered as a performance measure. Some industry measure the time required for the material handling system to deliver a specified set of loads.

Station queues: Mean load waiting times

The mean load waiting time is defined as the mean time loads wait in queues for material handling transportation. These queues are located either at processing stations or at separate load transfer stations.

Station queues: Mean queue lengths

The mean queue length is the mean number of loads waiting for a material handling vehicle over a specific length of time. The variance of queue lengths may also be of interest, as a means of examining the adequacy of the physical space provided for the queue. Blocking occurs when a workstation‘s output queue (or buffer) is full and the workstation can no longer place completed parts into this queue. Starvation occurs when a workstation‘s input queueis empty.

Material handling system cost

Material handling system costs may be comprised of variable and fixed costs. Variable costs are generally the operating costs of the material handling system. These costs can include the cost of power, lubricants, and maintenance. The variable costs may also include the routeing or travel expenses, which are proportional to the distance travelled.

Costs associated with idle or waiting vehicles may also be included in the variable costs. Fixed costs include such costs as the construction and purchase of equipment and hardware.

In addition to the use of total cost as a performance measure, cost ratio (C) is also used as a performance measure. This cost ratio is defined as:

C= C in/ C out

Where:

C in - moving cost of one unit load and one unit distance within a department, C out - moving cost of one unit load and one unit distance between departments.

Material handling system flexibility

Industry has identified range and response as dimensions of flexibility. Range refers to how much the system can change. Response refers to how rapidly and cheaply the system can change. It has been defining material handling system flexibility as the material handling system's ability to reconfigure (to handle new material flows) and the material flow capacity. They define material handling system flexibility for a vehicle based system as:

Fmhs = sum $xi^1it\ i^2ib$ i,

ni=1

Where

xi number of equipment of type i,

^{1}i max unit load quantity factor, based on capacity of the equipment,

t i equipment speed, based on the normal operating speed of the equipment,

e i equipment loaded travel factor,

b i relative rerouting cost, indicates ability of equipment to reconfigure.

Congestion

Congestion prevents vehicles from travelling freely on a guide path. As a result of congestion, vehicles may travel at reduced speeds or may be required to stop. Vehicles may be delayed by other vehicles blocking the path or at intersections.

Congestion levels may be measured by the following quantities:

- Vehicle Blocking Time: the total blocking time of the vehicles is defined as the time where vehicles are unable to move due to other vehicles
- Track Blocking Percentage: track blocking is defined as the blocking time (as a percentage) for track segments due to vehicle interference
- Track utilisation by averaging the utilisation of all track segments and then dividing by the number of AGV's (Automatic Guided Vehicles)
- Vehicle Waiting Time at Intersection: average vehicle waiting time at intersections

Congestion index

The congestion index (Ic) is defined as:

Ic =TA/TS

Where

TA the actual travel time,

TS shortest travel time if there were no congestion.

Characteristics of effective performance systems

For most systems, the selection of performance measures is not simply a question of determining which measures are `good' and which measures are `bad', and selecting the `best' one or the `good' one.

On the contrary, performance measure selection is the process of defining a set of measures that possess the following characteristics, all of which are found in any effective performance measurement system.

- **Inclusiveness:** The performance measure (or performance measurement system) should measure all pertinent aspects of the material handling system. In this way, good performance of one particular component of the system would not be possible without similar performance of other system components.
- **Universality:** The performance measurement system should allow for comparison under a wide range of operating conditions. That is, if two competing material handling system designs must be compared, then the measurement system should allow for this comparison, even if the system characteristics differ significantly.
- **Measurability:** All data required by the measurement system should be readily measurable. Furthermore, the process of measuring the performance of the material handling system should occur with a minimum of measurement errors and at a reasonable expense.

- Consistency: The performance measures used should be consistent with the overall goals of the organisation. The value of the performance measure should therefore provide meaningful insights into overall material handling system performance with respect to organisational objectives.

Numerous performance measures have been used to analyse material handling systems. Although traditional manufacturing system measures, such as job throughput, have commonly been applied to material handling systems, they do not measure the material handling system independently.

In these instances, the performance of the material handling system is confounded with the performance of the manufacturing system. Therefore, these traditional measures are not necessarily effective or appropriate in the analysis and design of material handling systems.

Multiple performance measures provide more comprehensive information about system behaviour. In fact, the use of multiple performance measures results in more efficient and effective system designs and operation. Although multiple criteria decision making has largely been ignored as a decision tool, it has been established as the most appropriate method for the simultaneous consideration of multiple performance measures in material handling system design and analysis.

Material handling systems are unique in the sense that they are degradable systems. That is, a failure of one or more material handling components does not necessarily indicate failure of the entire system. Indeed, system component failures may only indicate that the system will continue to perform its tasks, but at some reduced level of performance.

Therefore, neither traditional notions of performance nor reliability alone are appropriate in this context. Performability measures, then, which simultaneously measure performance and reliability, emerge as appropriate measures for use in the design and analysis of material handling systems.

Further Reading:

- ✓ ***Structuring Warehouse Management by Nynke Faber 17 September 2015***
- ✓ ***Practical Handbook of Warehousing by Kenneth B. Ackerman***